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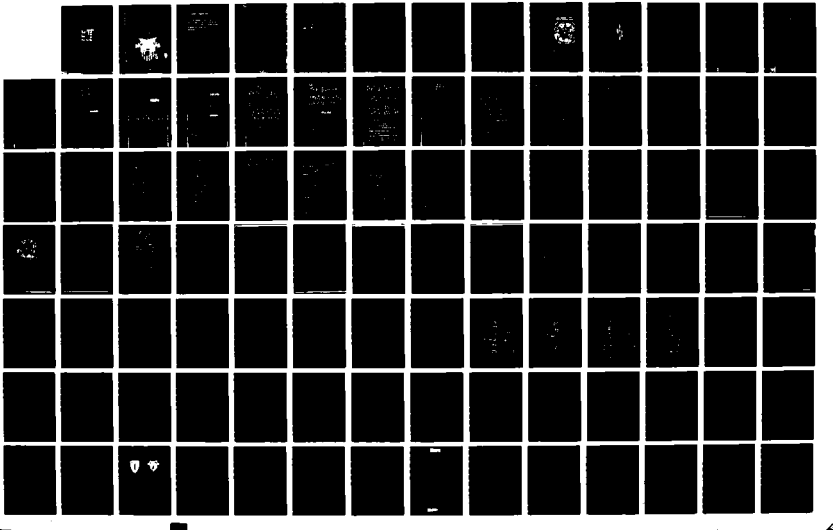

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JUNE 1985

COMBAT MODELING EVALUATION

AT

THE UNITED STATES MILITARY ACADEMY

By

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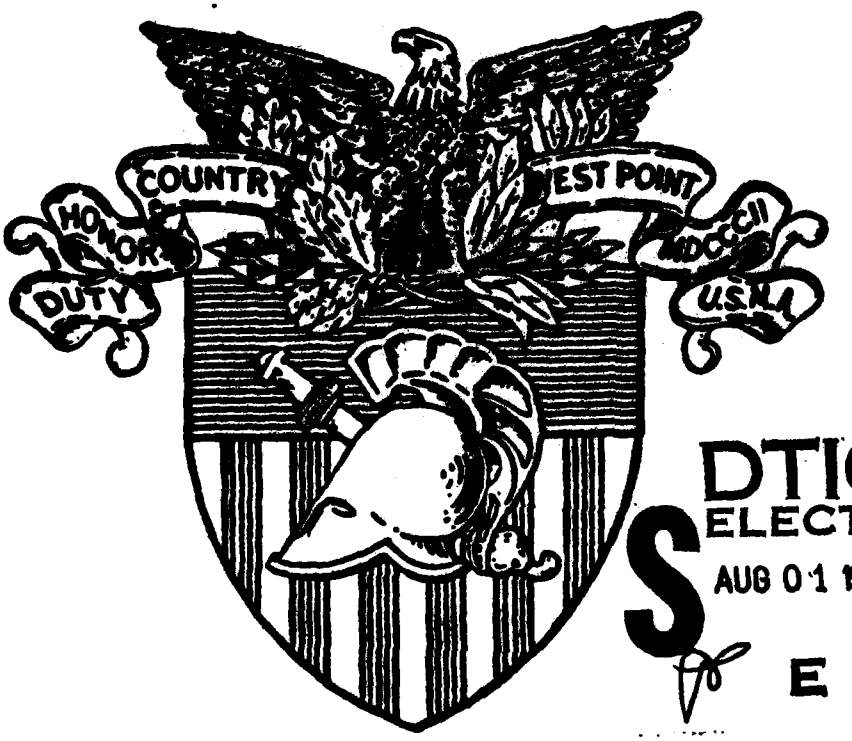
West Point, New York 10996-1779



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The McClintic Theater Model (MTM) is a large scale, analytic and stochastic simulation, computer assisted theater level combat model. The model has two major uses at the United States Military Academy: (USMA) as an educational and a research tool for cadets and faculty. In the operations research curriculum, the cadets study MTM's application of operations research techniques. These techniques are aggregated into a three day extended laboratory exercise in combat modeling. Several cadets have performed individual research

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20. (continued)

projects on the structure and parametric behavior of the combat attrition subroutine in the model. Future cadet research will focus on parametric analysis of other subroutines and on applying similar methodology to the Joint Theater Level Simulation (JTLS) model. Officers of the faculty are involved in a research project to validate the structure and input values of MTM and JTLS. This research is a unique effort to validate a large scale combat model in both the analytic and the military history arenas. This paper discusses cadet and faculty research in detail to include overall scheme of research and emerging results.

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FORWARD

The purpose of this report is to consolidate, preserve, and disseminate research performed by Cadets and Faculty of the Department of Engineering, United States Military Academy, on the McClintic Theater Model (MTM) and the Joint Theater Level Simulation (JTLS). This research was initiated at the request of, and partially sponsored by, the Army War College. The basic paper in this report is a chronology and summary of the research performed. At the appendices are individual reports of separate research efforts. These reports are internal progress reports which are presented as received from the original authors.

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ABSTRACT

The McClintic Theater Model (MTM) is a large scale, analytic and stochastic simulation, computer assisted theater level combat model. The model has two major uses at the United States Military Academy (USMA) as an educational and a research tool for cadets and faculty. In the operations research curriculum, the cadets study MTM's application of operations research techniques. These techniques are aggregated into a three day extended laboratory exercise in combat modeling. Several cadets have performed individual research projects on the structure and parametric behavior of the combat attrition subroutine in the model. Future cadet research will focus on parametric analysis of other subroutines and on applying similar methodology to the Joint Theater Level Simulation (JTLS) model. Officers of the faculty are involved in a research project to validate the structure and input values of MTM and JTLS. This research is a unique effort to validate a large scale combat model in both the analytic and the military history arenas. This paper discusses cadet and faculty research in detail to include overall scheme of research and emerging results.

Additional keywords: war games

1. INTRODUCTION

The decade of the 1980's has been marked by rapidly developing and geographically diverse crises. In response, the Departments of Defense and the Army perceived a need for a large scale combat model which could quickly provide battlefield simulation results to assist in the analysis of contingency plans. An additional requirement was rapid configuration of model parameters and data base to facilitate simulation of combat at varying levels, against varying opponents, throughout the globe. The majority of existing combat models are high resolution, that is requiring detailed data on individual weapon system performance and terrain. The McClintic Theater Model (MTM) was designed to overcome the detailed data requirements, and resultant preparation time, of existing combat models.

MTM is a hybrid analytic/simulation/wargame combat model. As such, certain combat functions are depicted by mathematical equations (analytic) such as combat attrition which is modeled by differential Lanchester Equations. Other combat functions are represented by stochastic simulation utilizing pseudo-random number generation. The opposing decision makers and their staffs are afforded active participation in the conduct of the conflict through normal staff actions and decision making. This interactive feature of MTM renders it a wargame. Hence the term hybrid combat model.

MTM was designed by Mr. Fred McClintic at the Army War College (AWC) in 1980. The initial objectives for development of the model were to enhance the AWC wargaming curriculum and to assist with the AWC Tactical Command Readiness Program. This program provides a basis for evaluating and modifying commanders' strategy and tactics through analysis of combat simulation results. Additionally, MTM found early use in the Army Chief of Staff's Contingency Planning Seminar in November 1980. Since that time MTM has been utilized by numerous Department of Defense analytical agencies and operational commands including the Joint Chiefs of Staff, European Command and its subordinate commands in Europe, Eighth U.S. Army in Korea, and Central Command (the Rapid Deployment Force) in the U.S. Interest in MTM is so intense that a contract is in progress with Jet Propulsion Laboratory to improve on the MTM methodology in a new model entitled Joint Theater Level Simulation (JTLS).

As use of MTM as an analytic and educational tool expanded, the user community became interested in the validity of the model and its database. The larger and more detailed database in JTLS has increased interest in model validity. The purpose of this paper is to detail ongoing efforts to evaluate and validate MTM and JTLS.

2. MODEL DESCRIPTION

(This description is based on Reference 8).

Model Capabilities

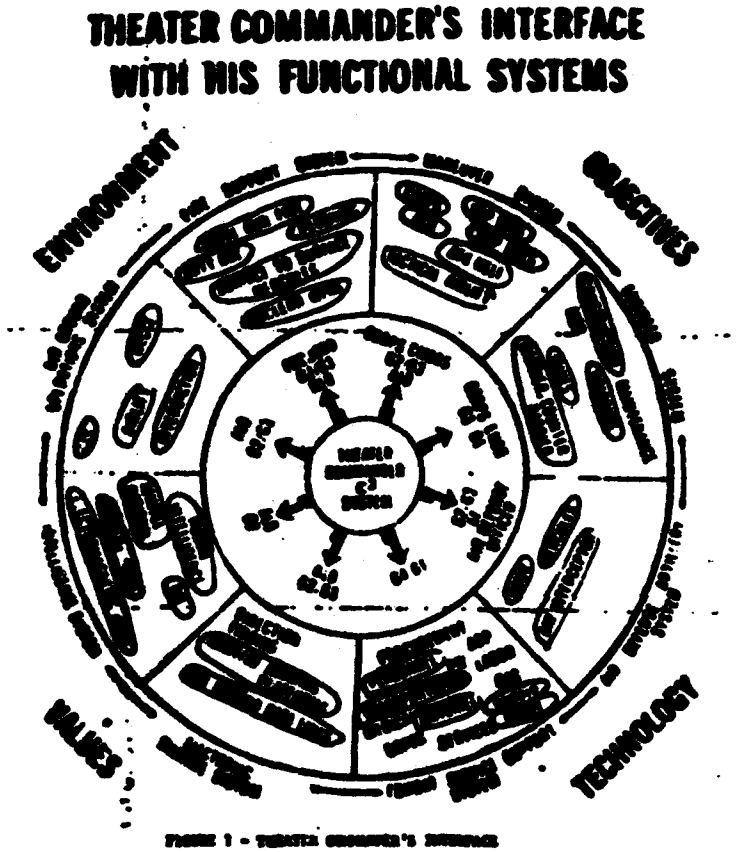


FIGURE 1 - THEATER COMMANDER'S INTERFACE

The MTM was developed around the diagram shown in Figure 1 - Theater Commander's Interface. Figure 1 depicts the Theater Commander's (a theater is a large battle area such as the continent of Europe) interface with the available functional battlefield systems. The items circled in Figure 1 are modeled in MTM. Those not circled are not yet simulated by MTM, but could be added in enhancements such as JTLS. Captain Robert Deas, in his presentation at the 1982 Workshop on Modeling and Simulation of Land Combat (3), described MTM in detail. Table 1 summarizes the key features of the model.

Model Structure

MTM consists of a main program (MAIN) consisting of 36 subroutines and functions, and an input/output program (IOPROG) which allows simultaneous input/ receipt of information to/from red, blue, and controller participants; a data base (WAR*DATA) which contains terrain, barrier, unit and miscellaneous information; and an ancillary data base building program (FIRST). MTM MAIN is a top-down structural program as shown in Figure 2.

TABLE I. KEY FEATURES OF MTM

- Easy to Use (Free-Form Keyword Inputs)
- Fast Running and Preparing
- Input Checking
- Integrated Battlefield (Army, Navy, Air Force, Nuclear, Chemical, EW)
- Variable-Size Hexagonal Grid
- Applicable to Any Part of the World
- Single Theater or Multi Theater
- Easy to Modify (Top-Down Structured Program)
- Restart Capability
- Multiterminal Operation
- Manual Simulation of External Events
- Compatible with Graphics Hardware
- Time Driven (Not Red/Blue Turns)

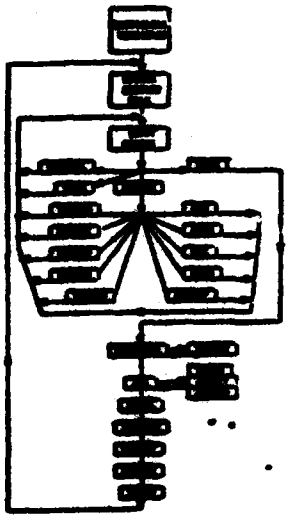


Figure 2. MTM MAIN Flowchart

A unique feature of MTM MAIN is the RESTART subroutine which periodically files a current wargame status. This feature allows the players to simulate alternative decisions after play has proceeded past the decision point. Such alternative analysis finds great utility in evaluating strategy and tactics or in researching the model. RESTART allows the wargame to be reinitiated at the point in time of the selected RESTART file.

The communication flow between MTM and the players occurs continuously. This is a unique advantage of MTM facilitated by the IOPROC buffer program. Many wargames use next-event procedures in which users can only enter orders during certain phases. IOPROC stores player input and MTM MAIN output. During the INPUT subroutine player inputs are loaded from IOPROC at appropriate points in MTM MAIN, outputs are down loaded to IOPROC. The time sequencing of these actions is transparent to the players who perceive real-time interaction with the model.

WAR*DATA satisfies the requirement for a rapidly configured data base. It stores all input values which are dependent upon the specific terrain or units involved in the wargame. Alternate WAR*DATA files allow rapid transition from one scenario of interest to another. The files are created through an interactive database building program entitled FIRST. This program queries the players or controllers on attributes of the terrain and units which it then loads, in proper format, into WAR*DATA.

3. COMBAT MODEL RESEARCH AT USMA

Model Validation Program

Origins

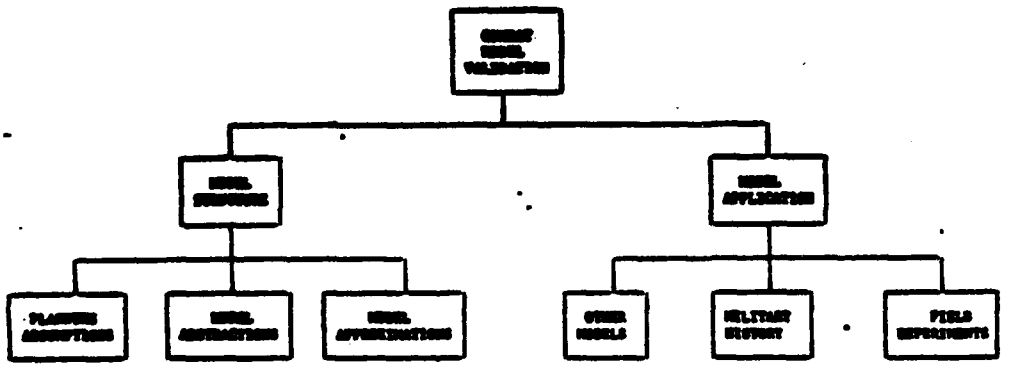
In response to a 1983 request from the Commandant, US Army War College (AWC), a Model Validation Program (MVP) has been instituted at USMA. The primary purpose of the MVP is to assist the AWC in providing combat model users with "confidence statements" about the outcomes obtained from combat models, particularly MIDM and JTLS. MVP is a joint effort of the Departments of Engineering and History. Faculty members are currently pursuing the research in addition to normal instructional duties, while the author is devoting full-time effort to the research during Academic Year 1984-85. The purpose of this project is to develop a methodology for the validation of large scale, low resolution combat models which contain stochastic elements. This methodology can then be applied to current and proposed models to increase confidence in analyses utilizing the models.

Methodology

In order to evaluate the level of confidence pertaining to results derived from a particular combat model, it is necessary to perform sensitivity analysis upon numerous parameters and at various levels of aggregation in the combat model of interest. A detailed analysis of the effect of key parameters on predetermined output measures of effectiveness must be coupled with an analysis of the model's overall fidelity with past, present, and anticipated battlefield conditions.

Current validation researchers concentrate on high resolution combat models which contain detailed modeling of stochastic combat processes. Low resolution combat models aggregate stochastic combat processes into stochastic sub-models and/or deterministic models such as the Lanchester Equations. Validation of such large scale, low resolution combat models represents a relatively untouched area of research and constitutes a significant contribution to the combat modeling community.

Figure 3.



A basic combat model validation approach, which forms the procedural basis of the MVP, was developed by Dr. Wilbur Payne of the TRADOC Operations Research Activity (7). As shown in Figure 3, this approach considers both model structure and model approach. Planning assumptions are analyzed to determine the validity of the inherent tactical, doctrinal, and organizational attributes of the model as well as the validity of internal and input parameter values. Model abstractions are reviewed to determine the validity of omitting or aggregating combat factors or interactions. Model approximations are considered to analyze the validity of approximating a combat factor or interaction through modeling simplifications.

Concurrent to validation efforts on model structure are efforts to validate model application. Both input and output values from the model of interest can be compared with values from other generally accepted combat models. One can gain confidence in the model by modeling historical battles. The fidelity of the model to historical results, or indications of why the model did not replicate history, provides valuable insights. Although actual combat cannot be generated to validate a model based on current doctrine and weapon systems, technology such as laser scored field exercises and instrumental training areas, are currently generating "combat" results which could be useful in validating models.

Throughout the validation effort, consideration should be given to the intended utilization of the combat model. In the Army operations research community, combat models are used for such diverse functions as weapon system analysis, force development, training aid development, cost analysis, individual training in schools, operational unit training, and analysis of operational plans. The purpose of using a combat model in each of these applications is different. Several factors of the validation process, such as input requirements, run time, data preparation time, model resolution, output format and resolution, and fidelity of output to the real world, are influenced by the intended uses of the model. One model may be valid for use as an individual training model, yet totally unsuited for use in weapon systems analysis.

Department of History

A unique aspect of MVP is the participation of the Department of History. This organization possesses expertise on military history and historical wargaming. A faculty group has developed MTM databases to allow wargaming of World War II battles. Their main purpose is to address the fidelity of MTM with historical results. They are investigating such questions as: useful sources of historical data for use in MTM, methodologies used to convert terrain and unit data into an MTM data base, validity of combat parameters within MTM, and critical factors which cause MTM not to replicate history. A second objective is to assess the usefulness of a computer wargame, such as MTM, as a tool for obtaining historical insights such as: the combat factors that were most critical, the effects of changing battle events or factors, and model differentiation between the results of a good and a poor battle plan and execution.

The historical analysis will assist the quantitative analysis by identifying shortfalls in the MTM battlefield environment or in the depiction of primary combat functions. This analysis will investigate questions such as: primary combat functions not modeled within MTM, primary combat functions within MTM which appear to be unrealistically modeled, combat results from MTM which appear to be unrealistic, and the appropriate levels of units that MTM models effectively.

Another area of emphasis will be to explore the possible pedagogical applications of MTM within the Department of History. This analysis will address: modifications required to FIRST, the data base building program, to facilitate its use in historical analysis, modifications required to MTM to facilitate its use in historical analysis, and additional output media that would facilitate historical analysis.

Cadet Research

MTM Combat Subroutine Structure

There have been four cadet individual research projects conducted on MTM and two on JTLS. The purpose of the first research project was to examine the combat subroutine of MTM by focusing upon two areas (4). The first area was the descriptive aspect of the subroutine. This included the development of the dendritics for the subroutine. The second area of attention was the analysis of the subroutine through regression techniques. This analysis served as a foundation and basic framework for future analysis in the MVP.

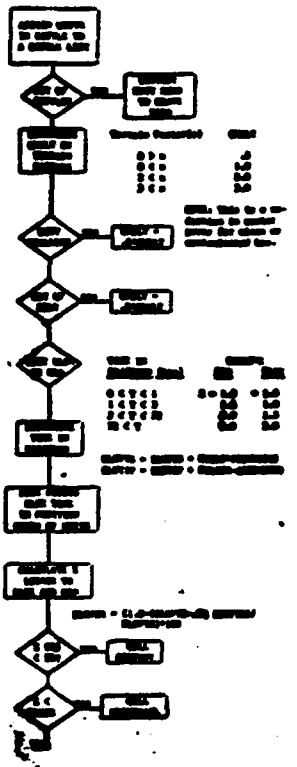


Figure 4. COMBAT Subroutine Flowchart

A major step in the analysis of the combat subroutine was the creation of the flow chart for the subroutine (Figure 4). This was the first flow chart developed for any of the numerous subroutines used in MTM. The flow chart provided insights into what key factors help determine the results of combat to include: the supply level of the unit in combat, whether a unit is stalled in a mined or contaminated hex, whether a unit is out of petroleum products, the terrain which a unit occupies, and the time the unit has been in that location.

Flow charting of the subroutine raised some important questions concerning the parameters which are used in the subroutine in order to resolve combat. A unit will enter the combat subroutine with an amount of points which reflect the unit's strength. The points are then multiplied by a CMULT factor which is dependent upon the time, terrain, and other factors mentioned above. The parameters of the CMULT factor were highlighted as a critical area for future research.

The second aspect of the research was the analysis of the combat subroutine outputs. This portion of the study resulted in two accomplishments. First, a data collection methodology was established which has been used in further analysis. The methodology includes the creation of additional subroutines which capture data points for the factors being studied. Once the data files were generated, a method for analysis using the Statistical Package for the Social Sciences (SPSS) was established. This included the writing of an SPSS program and production of initial SPSS outputs.

MTM Program Revisions

The second cadet research project was concerned with transitioning MTM from the UNIVAC to the replacement PRIME system at USMA. This involved revisions to operating commands and to the program's file structure. Concurrent to this transition, the format of the

(2) It makes lower level decisions based on a prescribed set of rules. For example, it may determine when small units withdraw from battle due to a predetermined cummulative loss threshold. Or, it may determine when and how two small unit opposing forces become engaged, based on prescribed decision rules. The quality of a model is sensitive to the automated decisions and in so far as possible a model should keep these to a minimum.

3. Potential Planning and Studies Methodology Using War Gaming.

a. Studies and Plans.

(1) This type of effort is characterized by J-5 activities where analytical effort is directed toward potential, but not necessarily evolving, problem areas. Analytic teams would consist of a proponent team (for example from the J-5 staff to include support from other agencies as appropriate), adversary team (analysts from an agency such as the DIA) and a control team (SAGA analysts). In addition, if the effort is to culminate in an operations plan it would be appropriate for staff representation from J-3 to be on the proponent team.

(2) It appears that for an effort such as this it is appropriate that the study/planning process incorporate two war game models: one of high fidelity and very fined gained to provide verification of study results, and a coarse grained parametric model through which sensitivity and contingency analyses can be made. Analysis supporting a plan or study could reasonably follow a sequence (as summarized in figure 1).

(a) Acquire validated data regarding the aspects of warfare in the region to be studied. This can be accomplished by researching actual data if there has been recent activity or it can be gained through simulation with the fine grained model, e.g., a war game with the Total Forces Capability Analysis procedure.

(b) Adjust the parameters of the parametric wargame model so that wargaming results between the validated data and this model are in agreement. Here one is talking about a model (the coarse grained paramentric model) in which a single variable (paramenter synthesizes a number of descrete activities on the battle field). These surrogate variables are then adjusted so that events in the parametric model yield results that agree with the validated data. One should not be fooled into believing that "tuning" the model is a simple issue. It will take a significant effort to even define what is meant by agreement!

(c) Wargaming is begun in earnest using the coarse grained model to automate the play. Because the coarse grained model allows for rapid play, many alternative paths can be played, i.e., when reasonable alternatives exist for an opponent. For example, one force would have as alternatives a surprise attack or a deliberate attack. Each may be gamed to assess the longer term implications. As one might observe, the number of

2. War Gaming as a Planning Tool.

a. A review of the study and planning processes within the JCS shows that, in general, they are not structured to account for a responsive enemy, e.g., an enemy who alters his situation based on US initiatives. There is no insurance that a study or plan has systematically examined the field of reactions an adversary might take given a shift in allied posture. Perhaps more important, there appears to be no formal structure to insure the examination of potential enemy actions and allied counteractions over time. In 1978, the Defense Science Board formally recognized this as a problem in all strategic analysis and suggested wargaming as the most favorable method for overcoming the problem. All evidence indicates this is true for all analysis.

b. War Gaming and the Joint Chiefs of Staff:

(1) A war game, as used in this context, is a structured procedure modeling various aspects of warfare between two or more antagonist forces. The actions of each force is directed by a group of analysts who are governed by a prescribed set of procedures. When battle is joined, the outcome is determined by a prescribed set of rules. The quality of a game is determined by how faithfully it represents the various aspects of warfare.

(2) In the JCS planning setting, a quality game would allow examination of a full spectrum of options available to opposing forces, thus providing a better assessment of needed resources to insure successful plan execution. This includes a full assessment of reserve and contingency force requirements, a more complete set of contingency plans, and a better definition of the essential elements of intelligence, i.e., those activities that would prestage a change in an enemy's operation.

(3) Should a gaming procedure be adopted for JCS planning and study efforts, one would expect war games to be established for each plan/study. Two gaming setups would be desirable; one which would be pursued by opposing analytic teams, for the purpose of assisting the development of contingency plans; the other would maintain the current situation so that should immediate analysis be required (as in a crises situation) operations personnel could use gaming procedures to explore the impacts of immediately available options.

c. Automation must be introduced to any such gaming procedure; otherwise for a wargame reflective of any reasonable fidelity, the necessary resources would be prohibitive. Automation serves two key functions:

(1) It serves as a secretary/bookeeper, providing a record of all activities in the game. If carefully designed, it also provides a record of decisions made by the analyst. In addition, automating the wargame allows routine events to occur such as convoy movement and fuel and ammunition consumption to be accomplished without attention.

ENCLOSURE A

1. Background.

a. The time urgent nature of a number of the planning and study issues faced by the Joint Staff make it imperative that a quality, rapid response analytic capability exist. General dissatisfaction in this regard has been expressed by the Chairman and other senior members of his Staff. In response, the Studies, Analysis, and Gaming Agency (SAGA) surveyed available analytic methods and concluded that the McClintic Theater Model (MTM) offered the greatest promise. Two officers from the US Military Academy, Major John Edwards and Captain Robert Dees were assigned to SAGA for 30 days to assist in the evaluation of MTM. Captain Dees examined the structure of the model and provided an assessment of its potential to model conflict; his report is forwarded under separate cover. Major Edwards examined how the MTM might be employed by the Joint Staff and the result of that effort is herein reported. His specific tasking is found at Annex 1.

b. Major Edwards' effort included:

(1) A review of the background literature cited in the bibliography. This provided a general understanding of the organization and division of responsibilities of the Joint Chiefs of Staff, understanding of MTM, and an insight of War Gaming as a tool to support studies and plans.

(2) A visit with Mr. Fred McClintic, the author of MTM, to gain his perspective on the model.

(3) Interviews and limited analytic support for action officers from SAGA and the J-5 staff.

- Provided analytic effort to LTC Lynch in support of the Force Mix Study.

- Reviewed OPLAN 1003-81.

- Discussed the Total Force Capability Analysis effort with LTC Shinol.

- Contacted other individuals to include personnel from the J-5 - Col Moory, Col Eggers, LTC Linehard; and personnel from SAGA - Captain O'Neill, Colonel d'Alelio, LTC Timberlake, LCDR Swan, Major Weber, and Major Markwardt.

(4) Attendance at briefings, to include the JCS Action Officer orientation and a presentation by Mr. Girshwin, OASD, describing an effort to implement War Gaming for Strategic Analysis.

c. The attractiveness of the MTM as a tool for quick dependable analysis is that it is a gaming process rather than model. The two-man month effort of Major Edwards and Captain Dees has concluded that the MTM nas excellent potential for the quick analysis role. Furthermore, it appears well suited as an integral part of a general study methodology. While a more complete discussion of the model structure is found in Captain Dee's report, it is appropriate here to discuss MTM's flexibility. It's modular structure is ideal for developing families of subroutines that will allow analysis over a full-spectrum of detail, that is, the model can be easily taylored to study requirements.

3. Conclusions.

a. Implementing a formal war gaming structure to the planning process will insure better quality analysis in that it will examine the impact of a responsive enemy.

b. In the above context, MTM is an excellent prospect for a rapid response method of analysis.

4. Recommendations.

That necessary resources be allocated for the timely development of the McClintic Theater Model:

(1) Dedicated Main Frame Computer Resources.

(2) Substantial Command Control Technical Center personnel effort to implement and support model development.

(3) Dedicated Technical Services Division analysts to supervise model implementation.

JOHN R. EDWARDS
MAJ, AD

THE JOINT CHIEFS OF STAFF
WASHINGTON D.C. 20301

MEMORANDUM FOR THE SCIENTIFIC AND TECHNICAL ADVISOR, SAGA

Subject: Report of Study of a Methodology for Quick Reaction Analysis

1. Background.

a. The Chairman of the Joint Chiefs of Staff, his military assistant, and the J-5 have expressed a desire for the Studies, Analysis, and Gaming Agency to develop methods for conducting quality analysis in time urgent situations. In response, the Technical Support Division has conducted a search of existing methodologies and has determined that the McClintic Theater Model (MTM) offers favorable promise.

b. Major Edwards and Captain Dees, United States Military Academy, each were assigned 30 days of temporary duty to SAGA to support the evaluation of the MTM. Captain Dees was to examine the structure of the model and Major Edwards was to determine how the model might be employed within the Joint Staff. The specific tasking for Major Edwards is found at Annex I to Enclosure.

2. Discussion.

a. To assess potential roles for the MTM, Major Edwards reviewed the joint planning/study process and matters relating to it. The findings of this effort collaborate a concern voiced by the Defense Science Board in 1978: That there appears to be no specific method to insure a responsive enemy is considered in analysis supporting strategic planning. That is to say, there are no identifiable procedures to insure plans and studies consider a full spectrum of possible responses to US initiatives. There is no apparent reason that this is not also an issue with analysis supporting most strategic studies. In consonance with the Defense Science Board concern, Major Edwards pursued his study in the broader context of determining a study methodology that has the potential to represent this aspect of analysis.

b. With enunciating its findings in 1978, the Defense Science Board suggested that employing a War Gaming Methodology was the most promising way to overcome the problem. The concept of using war games to develop plans has historical precedence; the Germans have employed this technique from the time of the Prussian Empire. The success enjoyed by SAGA's Total Force Capability Analysis, a finely detailed War Gaming procedure, further supports the option to employ a formal War Gaming Structure to all planning. A candidate wargaming proposal is found in the attached report (Enclosure A).

THE JOINT CHIEFS OF STAFF
WASHINGTON, D.C. 20301

OSTA 87-81
28 September 1981

MEMORANDUM FOR: See Distribution

Subject: McClintic Theater Model (MTM)

1. During the past summer, two members of the faculty of the United States Military Academy, Major John Edwards of the Department of Mathematics and Captain Robert Dees of the Department of Engineering, served a 30 day internship with the Studies, Analysis, and Gaming Agency of the Organization of the Joint Chiefs of Staff (OJCS).

2. Their primary assignment was to investigate the capabilities of the McClintic Theater Model (MTM), developed at the Army War College, to provide the OJCS with a viable rapid response wargaming tool for use in developing and analyzing plans, contingency operations, and exercises.

3. Major Edwards focused on developing a process for the OJCS to use a rapid response wargaming tool. Captain Dees conducted a comprehensive evaluation of the structure, methodology, and algorithms of MTM.

4. The reports that present the results of Major Edwards' and Captain Dees' efforts are enclosed. It is interesting to note that both Major Edwards and Captain Dees arrived at the same conclusion that the MTM is an excellent prospect for a rapid response wargaming tool for the OJCS.

WILLIAM G. LESE, JR.
Scientific and Technical Advisor
Studies, Analysis, and Gaming Agency

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Army War College
Dr Wilbur Payne, Dir. TRASANA

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The MTM attrition routine was, therefore, modified. As can be seen in Figure 9, the effects of the attrition routines are confounded with the effects of the timing mechanisms in the two models as one views X attrition as a function of the combat ratio. TACOPS utilizes a 6 hour time increment for Brigade level combat and 12 hour increments for Division level. The attrition rate remains constant, independent of time increment (A1). MTM, however, utilizes a two hour time increment for all levels of combat (M1). There is, therefore, a compounding effect of attrition when modeling 6 (M3) or 12 (M6) hours of combat in 2 hour increments. As a result of the interaction between the combat attrition routine and the simulation time increment, MTM can closely approximate, or exceed, the attrition rate of TACOPS.

JTLS Research

During the summer of 1984, faculty research also expanded to JTLS. Initial efforts centered on a user evaluation of the model during eight days of intensive wargaming at the ARC. Approximately 30 people were involved in this effort. Evaluation focused on a set of 184 user requirements for the model. The evaluation provided numerous comments on required changes and desired improvements for the model. Critical areas identified were: improvement of the database building program, improvement of the simulated to actual time ratio, better balancing of combat system modeling resolution, evaluation of the input data, and enhancement of naval functions modeling. The evaluators were very impressed with JTLS' potential as a theater model and recommended continued emphasis on rapid development and use.

Future Research

Future research will involve applications of the validation methodology derived on MTM to other models and further research on MTM itself. Initially, JTLS must be transported to the VAX system at USMA, a process which is almost complete. The Department of History will then be able to exercise the Kharkov and Ardennes battles on this model. The next phase of research will probably center on the heterogeneous Lanchester attrition coefficients in JTLS. Initially, sensitivity analysis will determine the statistical significance and inter-relationship of the coefficients. Then other combat models will be investigated to compare their input or output attrition rates with those in the JTLS database. Attrition rates could also be derived from historical data and experimental data such as that generated at the National Training Center, Fort Irwin, California. A related area of research would be to investigate the effects in JTLS of aggregating the level of Lanchester attrition modeling. Faculty members are also exploring the possibility of working with other models such as brigade and division level models resident at TRASANA and the models of the Army Model Improvement Program.

4. SUMMARY

This paper has summarized the capabilities and structure of MTM, and the USMA research efforts being devoted the MTM and its successor, JTLS. The Model Validation Program has institutionalized USMA's commitment to combat modeling research. With the interest and resources now in position, one can be justifiably optimistic as to the contribution MVP will continue to make to the combat modeling community.

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Faculty Research

Department of History

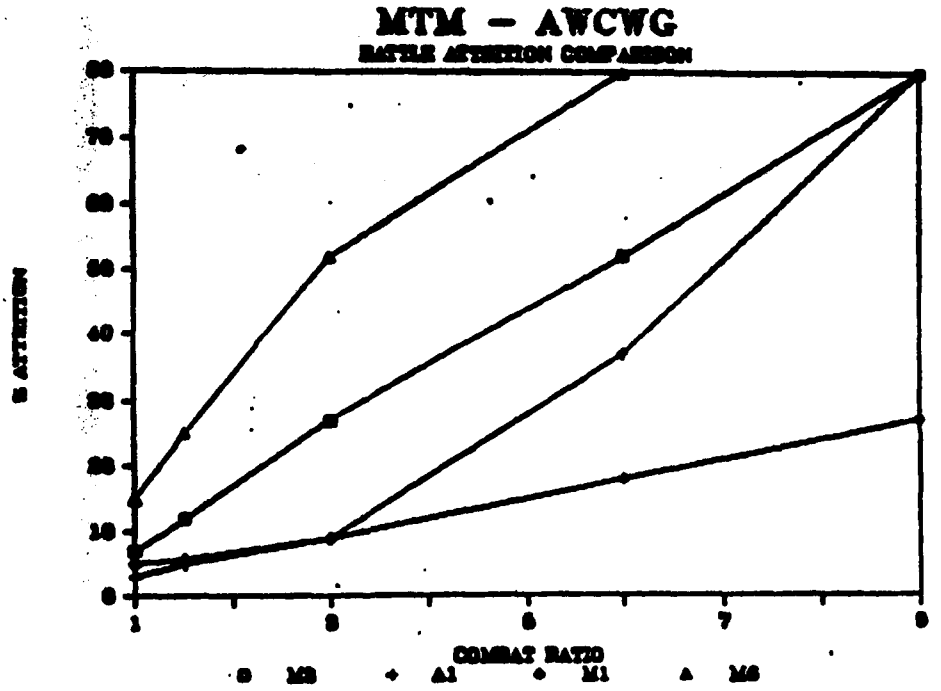
MTM related research by the Department of History faculty has concentrated on building unit and terrain database for the World War II battles of Kharkov and the Ardennes. This preparation has necessitated research into historical reports and analyses of the battles to include combat reports from the units involved. The requirement for terrain data necessitated acquisition of period maps representing the 1940's terrain features. The terrain and unit databases have been configured and loaded. Test runs of the historical model are now in progress. This initial historical research effort will soon culminate in historical wargaming using MTM.

MTM Research

Initial Department of Engineering research on MTM entailed a detailed analysis of the internal operations and imbedded assumptions of the model (3). This research focused upon whether MTM performs the functions advertised and whether these functions are modeled using credible analytical techniques. The research culminated in a summary of 19 modifications which would eliminate many of the identified shortcomings. The conclusion of this investigative effort was that the MTM is an analytical tool which possesses considerable potential as a high-level planning and decision aid.

The second phase of the research was to analyze a micro-computer, MTM based, combat model entitled Tactical Operations Simulation (TACOPS). This analysis determined that 10 of the 19 suggested modifications to MTM had been addressed by TACOPS. Five additional enhancements to MTM were recommended. An interesting interaction between the combat attrition routine and the time increment of the simulations was derived. There was concern among AWC students that the attrition rate of a significantly superior force against an outnumbered force was not sufficiently high.

Figure 8.



Each unit's combat power is multiplied by modifying factors as discussed above to produce the friendly and enemy point values. These values are then inserted into the attrition equation to determine the loss rate for each two hour period. After all of the units' losses have been calculated, they are subtracted from the units' strength ratings. The combat subroutine reduces the percent rating and the unit strength rating only. Another routine depletes the appropriate amount of expended supplies.

The research concluded that the MTM combat subroutine performs exactly as it has been programmed. The major flaw in the attrition subroutine arise from the fact that it completely ignores the effects of weather or day/night conditions on ground combat. Another significant deficiency is the lack of any type of documentation available at USMA that states how the values used as unit strengths, terrain values, time in position modifiers and the .03 attrition rate coefficient are determined. The MTM combat subroutine does, however, provide a workable system to simulate ground combat attrition.

Further research must be performed in two areas: how to modify the program to simulate the effects of daylight, darkness and weather and what are the appropriate values to use as unit strengths and modifying coefficients. The MTM model could then be modified to provide a much more accurate simulation of ground combat attrition.

JTLS Research

During the summer of 1984, cadet research focus expanded to JTLS as that model continued development. One cadet designed a User Acceptance Test for the Model Interface Program (MIP). This program interactively controls the wargame terminals, verifies and stores input and output data, and translates this data to and from the Combat Events Program. The Acceptance Test was executed and provided valuable insights to the MIP(2).

A second cadet research project centered on the ground combat attrition process of JTLS (5). It was verified that JTLS uses heterogeneous Lanchester attrition. In this type of attrition modeling, combat systems attrit other combat systems at a rate specific to the two systems involved rather than an overall rate for a unit comprised of several different systems. It was also verified that the distribution of combat systems and their combat power throughout a game hex was modeled. This means that combat outcomes are dependent on the orientation of the attacker and defender relative to each other. An attack on a lightly defended side of a hex is much more likely to succeed than one on a heavily defended side. Finally, it was verified that attriting combat systems suffered penalties for fuel deficiencies and could not attrit other systems when out of ammunition.

Once these modeling factors had been verified, several model improvements, to include proposed mathematical models, were suggested. These improvements included more realistic area fire models, a penalty for victim combat systems who suffer from fuel and ammunition deficiencies, and time degraded attrition rates. Modeling the degradation of combat effectiveness due to prolonged combat is particularly important.

Current Research

There are currently three cadet research projects in progress. The first is an effort to organize, code, and input the data available on the Battle of Kharkov. This research is discussed in the next paragraph. A second current effort is a detailed examination of ground movement algorithms in MTM. This work is exploring how units are moved, at what rate, and what parameters influence, or don't influence, movement in the model. MTM movement rates will be compared with those in other models. The final current effort involves developing a methodology to aggregate output attrition rates from lower level models into input attrition rates for MTM. Model runs have been gathered from two accepted lower level models for this effort.

FIGURE 7.

EFFECT OF MINEFIELD ON COMBAT

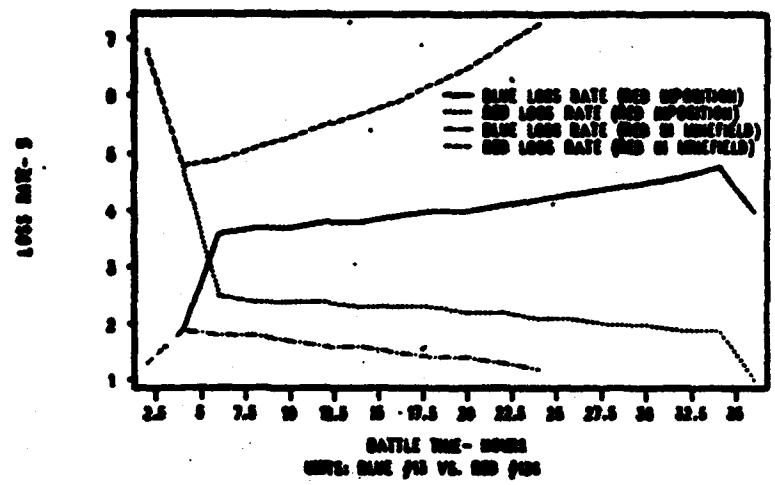
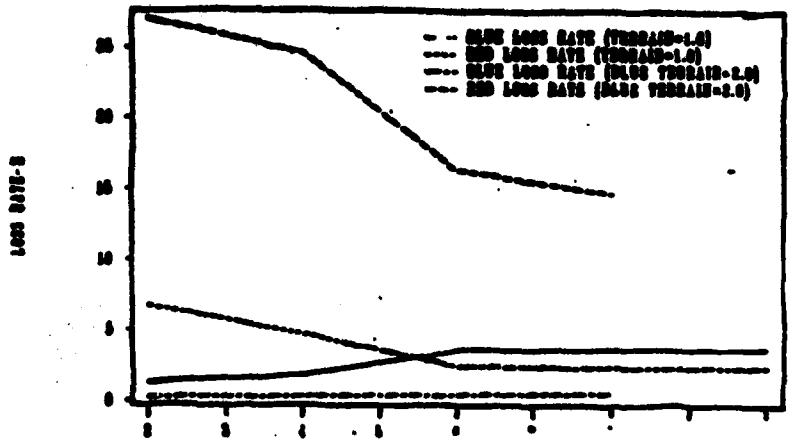


FIGURE 8.

EFFECT OF TERRAIN ON COMBAT



Day, night, and weather have no effect whatsoever on the combat process. No effect is coded and none is claimed in the users' manual. These parameters have an effect in other subroutines which in turn may affect parameters that do have an effect in the combat subroutine. This is an obvious weakness of the model. It cannot be assumed that all units in the theater are equipped with Standard Target Acquisition and Night Observation (STANO) devices or that the STANO devices make a unit as effective as it is in clear daylight conditions. It is reasonable to expect that attrition rates would decrease at night or during foul weather.

The effects of each posture are:

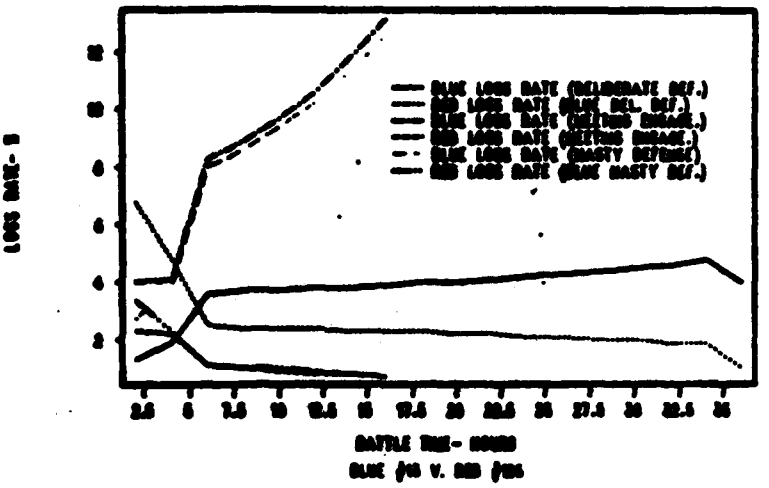
Meeting engagement does not change combat power.

Hasty defense results in a 50 percent increase in combat power.

Deliberate Defense increases power by 200 percent.

FIGURE 6.

EFFECT OF ENGAGEMENT TYPE ON COMBAT



Both the attacking and defending units are modified in this manner (Figure 6). Any unit that completely exhausts its supply of ammunition during combat is immediately destroyed. This occurs even if both units are out of ammunition at the same time. Any unit that runs out of fuel in combat is assessed a 50 percent reduction in combat power. Minefield attrition is assessed independently and concurrently with combat attrition. This is accomplished by a separate subroutine. Mines do not affect the ground combat attrition equation. The attrition from minefields is in addition to combat attrition. This makes sense from a real life point of view. Being trapped in a minefield would make a unit more vulnerable to attrition if it remained stationary, while the minefield would damage or destroy some of the forces if they attempted to maneuver to reduce their vulnerability to enemy fire (Figure 7). Units are not affected by Chemical or Nuclear contamination beyond the effects of the initial spray or blast. The users' manual predicts that a unit will lose one percent of its power every hour that it is in a contaminated hex. This does not occur in actual play.

Each hex is assigned a value representing the type of terrain predominate within the hex. The method for assigning a value to a terrain type is not completely explained, however, more restrictive terrain such as forested areas and urban areas are assigned higher values than less restrictive terrain such as open areas. Negative terrain values cut combat power in half. Positive terrain values less than two do not change the combat power. Values between two and three double combat power while values of three or more triple it (Figure 8). As mentioned before, the game does not discriminate between unit types in assessing terrain modifiers. In reality, different types of units are affected differently by various terrain types. In MBT, urban terrain triples the combat power of any type of unit. This may be true for an infantry unit, but few tankers would consider their units to be at an advantage in restricted towns and cities. In real combat, tankers would try to bypass urban areas but in the game it would be advantageous for tankers to move into urban areas to gain the advantage of the 3.0 multiplier. The terrain modifiers should be put into a matrix that indexes the multiplier by both terrain and unit types.

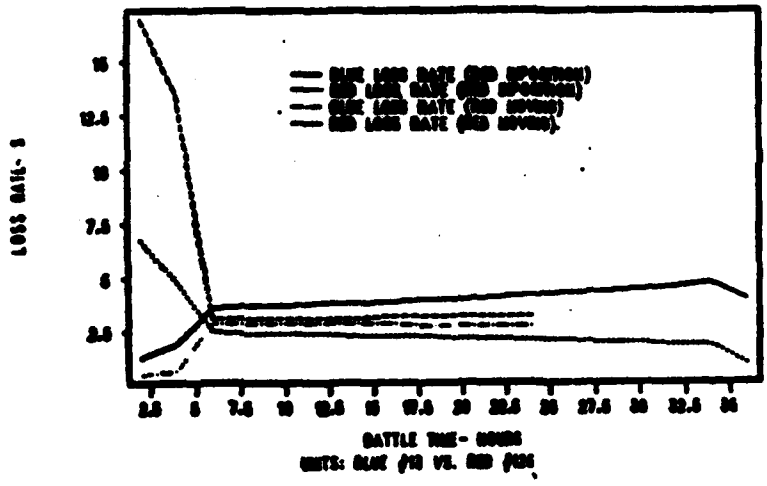
The source code was analyzed to determine the effect of each input parameter on the attrition equation. The data from each battle run was used to confirm this prediction.

The effects of each parameter are explained in this section along with the effects of daylight, darkness and weather. Unit Strength directly affects the attrition process through the variable points. This strength is multiplied by the modifying values of the other input parameters. The combat loss of a unit are reflected by a decrease in this strength. This is exactly as predicted in the program and user manuals. The only effect of the Unit Type parameter is to determine the actions that are feasible for a particular unit to perform such as air attack missions or indirect fire. It has no effect on ground combat. This is as predicted in the code and the user manuals.

Whether the attacking or defending unit is still moving toward its destination or has already arrived when it makes contact has a significant effect. Both test results and code analysis indicate that a moving unit suffers a 60 percent reduction in combat power for the first four hours of combat. This could be taken to represent the greater firepower that a unit which can deploy into a prepared attack formation would have over a unit that runs into the enemy while still in a march column type of formation. Four hours does, however, seem to be an excessive time period to penalize a moving unit. A unit should be able to recover from the initial shock of combat and deploy into an attack or defensive formation within two hours. The game designates the attacking side as the side with the shortest average time in position during each two hour period. This does not have any other effect on attrition (Figure 5).

FIGURE 5.

EFFECT OF POSTURE- MOVING V. NOPOSITION



The time that a unit has been in position is used to determine what type of defensive posture the unit is in. The posture significantly affects the units combat power. For Blue units:

Meeting engagement = time in position less than 3 hours.

Hasty defense = in position between 3 and 72 hours.

Deliberate defense = in position greater than 72 hours or at game start.

For Red units:

Meeting engagement = time in position less than 1 hour.

Hasty defense = time in position between 1 and 3 hours.

Deliberate defense = in position greater than 3 hours or at game start.

data base was revised to be compatible with new data bases at other MTM installations. This revision required alteration of every command that included a terrain hex designation.

Revising the database required revision of the FIRST database building program to accept the new terrain hex notation. Experience had shown that FIRST was not user friendly, and it was therefore revised to display input format error statements and to allow corrections to inputs. The interactive questions to the user were made more complete and self-explanatory.

MTM Combat Subroutine Analysis

The third and fourth cadet research projects on MTM began a sensitivity analysis of the effects of critical input variables on combat results[4,6]. The MTM ground combat subroutine uses a simple homogeneous Lanchester Equation dependent upon the modified strengths of the attacker and defender to produce attrition. The aim of the cadet projects was to determine how each of the input parameters modified the strengths of each combatant before the attrition was calculated and modified the resultant force levels as a function of time.

The effects of each of the input parameters was determined by both experimental analysis and analysis of the combat subroutine programming code. The object of these analyses was to determine whether the parameter affected combat as predicted by the source code and the game manuals. The experimental analysis involved conducting four separate battles simultaneously in each game run. Four battles were used to save time. A Soviet Tank Division attacked a West German Armored Division in each battle. Each red-blue pair was placed two hexes apart in an isolated part of the map. In each run the red (Soviet) unit would move into a hex adjacent to the blue (West German) unit and combat would begin. All of the input parameters were held constant except the parameter under investigation. The experimental output was the attrition experienced by each unit. This was then analyzed to determine how each input parameter affected combat.

Initially it was planned to conduct multiple runs of each experiment to determine the statistical variance of the results. This proved unnecessary when all runs of the initial sets of experiments were exactly the same, independent of game time, starting time or game speed for each set of input parameters. A subsequent analysis of the entire combat subroutine revealed that there were not any stochastic elements involved in the entire attrition process. All combat strength modifiers were determined directly by the values of the input values. All random combat attrition is a result of variations of the input parameters by the player or by other subroutines. This made multiple runs of each experiment unnecessary. Only two runs were made of each experiment to insure that the results were correct.

The source code for the combat subroutine was examined to predict the effects of each input parameter and to explain any unusual results. After much careful examination, the attrition process became very clear. It was then possible to follow the attrition process for any engagement. The attrition process functions exactly as programmed in the code.

It was necessary to understand how the MTM attrition process works to understand how the input parameters affect combat. All units are assigned a combat power value in the database. During combat this power is multiplied by values assigned to each input parameter. The attrition rate is generated using a simple homogeneous Lanchester-type difference equation. This equation is:

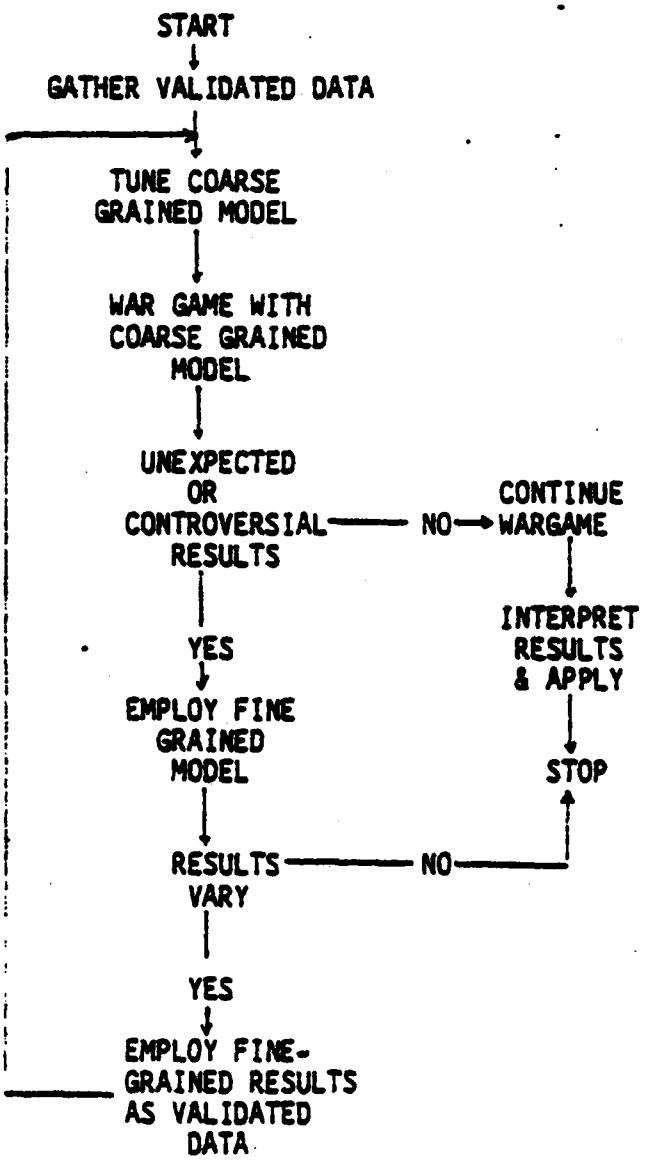
$$\frac{\text{Loss}}{2 \text{ hours}} = \frac{(1.-(\text{Friendly Points}-.03\ \text{Enemy Points}))^{*}100}{\text{Friendly Points}}$$

where:

Points = Unit Strength * Modifying Factors
Loss = Fractional decrease in Unit Strength.
Modifying Factors = The cumulative effect of the input parameters (CMULT).

FIGURE 1

POTENTIAL WARGAMING METHODOLOGY



branches that could be considered (a branch in the game is any point at which more than one reasonable course of action can be taken) over a long period would be prohibitive. Thus, in the near term of a game nearly all reasonable paths should be explored, but in the more distant time probably only the most likely courses of action should be considered.

(d) As new or questionable results are obtained in the wargame the circumstances leading to these results would be examined in the large fine grained model to verify the questioned results. Should there be differences, then the coarse grained model would be readjusted so that in the new circumstances general agreement exists with the fine-grained model. At this point the spectrum of issues under the questioned circumstances would be reexamined. If there is no variance between models the analysis continues with the coarse grained model.

(e) Insights gained from the wargaming are reviewed by all three gaming teams to interpret them into resource requirements and contingency plans.

b. Operations and Time Critical Studies. Characteristically, this circumstance is thought of as an area that had been under study by J-5 plans that has moved to crises stage in which actual operations are being made. J-3 becomes proponent for the analysis where the J-3 observer(s) now assume the role as the proponent team. All other teams remain as before, possibly augmented. Use is made of the prior analysis and resulting plan. Current analysis is made using the game reflecting actual disposition of forces. Wargaming is pursued only into the near term, but with all game paths considered. One would expect frequent recycling of the game where the base data is reset to reflect the evolving situation. The purpose of this type of analysis would be to provide insight into what immediate courses of action are available to an adversary so that maximum use can be made of contingency analysis accomplished in the planning phase. The procedure for this type analysis would follow as in paragraph a(2) except that the fine grained model would not be employed.

4. The McClintic Theater Model as a Candidate for the Coarse Grained Model.

a. (1) The McClintic Theater Model is a wargaming method that is time responsive. Complete theater exercises have been examined in less than 4 weeks, starting from problem definition and data base loading through game completion.

(2) It has additional appeal because it is easily altered. Its architecture handles the behavior of units modularly. The level of fidelity and the formulas for interaction between game units can be changed without reconfiguring the MTM base structure.

b. The current subroutines in the MTM have major shortcomings from a studies and planning perspective (they were designed to support training at the Army War College and high fidelity was not a priority concern). As it is currently configured, the model is valuable in providing insights into conflict.. However, supporting subroutines should undergo a number of changes. The most critical are:

(1) A logistics subroutine should be written that will reflect logistic constraints of a battle field. Mr. McClintic is currently writing one.

(2) Subroutines that better play the air war. In particular, surface-to-air engagements are badly represented. There are serious flaws in the air-to-air defensive subroutines.

(3) The communication subroutine should be improved so that the effect of communication traffic capacities can be played. Of particular importance is the effect of destroying relay nodes and the effect of enemy jamming.

(4) The attrition calculation must be improved so that there is a chain of logic connecting the configuration of a unit to its associated attrition parameters. See Annex 2 for a candidate.

c. An important consideration for improving the MTM is that each phase of the game (ground, air, and sea) be played with compariable grainularity. At Annex 3, is a proposed method for restructuring the MTM subroutines to address this concern.

d. One very important aspect of the MTM is that its adaptibility allows for various levels of grainularity. That is, one is able to develop a family of subroutines in which different battle resolutions can be gamed. This adaptibility can be used to examine the full range of study and planning issues and, thereby, further recommending the MTM as an analytic tool.

5. The McClintic Theater Model, JCS, and SAGA.

a. Internal SAGA Organization to Support the McClintic Theater Model.

(1) Once the proponent agency (J-5, J-3, C3S) for a plan/study has formed its team and has established an opponent team, SAGA provides a control team consisting of analysts from the appropriate division (Strategic Forces Division, Special Studies Divisions, or the Political Military Division) a Technical Support Division Analyst, and a CCTC element. Figure 2 illustrates the full gaming structure.

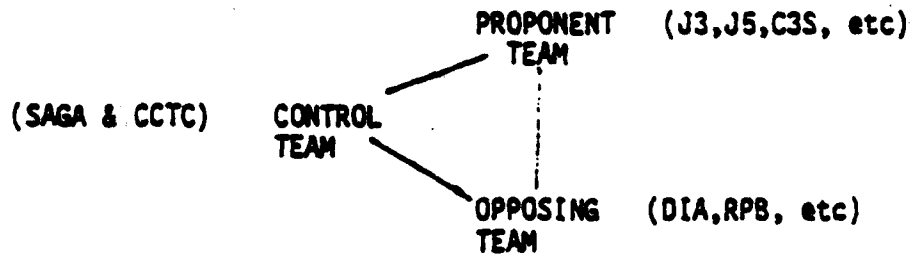


FIGURE 2

WARGAMING ORGANIZATION

The Control Team serves three purposes. One to translate the qualitative statement of the issue to be examined to quantitative terms; two, to determine the appropriate tools for addressing the quatitative problem statement; and three, to initiate the data base and maintain the war game effort A principal role played by the control team is that of quality control. It is this team's function to insure that the study effort remains free from either of the opposing teams "exploiting the model."

(2) Under this methodology of conducting studies, the Technical support Division would have to be augmented, by at least two personnel.

- A model interface analyst who would work with SAGA Study Analysts assisting them in using the MTM. He would serve as the support broker by determining and coordinating CCTC resources.

- A model development and configuration control analyst who would oversee the development of needed model improvements. Additionally, this analyst would keep abreast of other agencies modifications of the MTM for evaluation as to their appropriateness with the existing version of the MTM.

b. Administrative Support.

(1) War Gaming facilities would be required. Two possible alternatives are a centralized facility such as the one used by the Politico-Military Division or a decentralized operation requiring remote computer terminals in each of the team locations. The latter option would require considerable coordination.

(2) A substantial amount of programing support would be required of CCTC. An initial bow wave requirement would exist for implementing the model on JCS computers. In addition there would be a continuing requirement to service the model during gaming (it is expected that CCTC personnel would provide the interface between the analytic teams and the computer), as well as a continuing requirement to update and improve the model as the need occurs.

c. Computing Hardware.

(1) If MTM is to be implemented and used, the most critical support requirement is dedicated computer time. Current priority allocated for MTM is such that completing just initial moves requires a full day; an effort that requires a matter of minutes at the Army War College (where dedicated resources are available). No effort has been made to quantify the main frame requirements; however, it should be clear that if very many JCS study efforts incorporate war gaming, a substantial main frame resource will be required.

(2) Current remote terminal hardware needs to be upgraded. As a minimum, terminals comparable to the Techtronics 4054 with dynamic graphic option should be adopted. This will allow for quick, accurate loading of the base data for a game, as well as providing the analyst a visual picture of the game's current status. It would be very desirable that the terminals have a light pen capability that will allow data to be entered via the pen. This would further speed a study effort and would insure more accurate implementation of the analyst's desires.

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ANNEX 1

PROJECT FOR USMA FACULTY

1. PROBLEM. Develop a methodology for rapid response analysis:

- A methodology is needed for short term (measured in days/weeks) analysis of contingency plans and operations. The Chairman, his military assistant, and the J-5 have each remarked that SAGA's analyses provide detailed study at the expense of time, a critical resource to analysis of crisis situations. In brief, what is needed is a methodology which will permit sound analyses that result in feasible, alternative courses of action for any particular crisis--and most importantly, the methodology must be able to provide results to senior level decisionmakers in sufficient time to permit decisions and actions that can effect the crisis in hand.

2. DISCUSSION. The methodology should address the following:

- Historical background of the crisis.

- Political, economic, and cultural constraints.

- A range of possible US options--"do nothing," diplomatic action, military aid, military intervention, etc.

- For crises for which the US may not be directly involved, identify critical points which may prompt US reaction and then identify possible courses of action to follow.

- Resources required for each course of action.

- Impact of adopting each course of action (on other plans, policies, and national goals).

- Actions necessary to end the crisis.

- Post-crisis activities.

3. DESIRED RESULTS.

a. Written proposal outling a methodology for rapid response analysis to include identification of:

- Organization and Staffing.

- Administrative Support.

- Analytical Tools and Techniques.

- Computer Support.

- Procedures (flow chart of action).

b. Demonstration of the proposed methodology applied to potential (or actual) crisis situation.

ANNEX 2

AN ALTERNATE ATTRITION FORMULA

1. Homogenous Opposing Forces. In this case, each force is considered to have one type of weapon with which to attack the other.

a. The following quantities require definition to develop the attrition formula for the homogenous case.

- $S_i(t)$ is the strength of the i^{th} force at time t.

- $A_i(t)$ represents the strength of the i^{th} force element that is able to engage the opposing force. As in the MTM, this models the fact that it takes time to maneuver a unit so that all its forces are in contact. It seems that Mr. McClintic's approach is adequate in that $A_i(t)$ increases at a prescribed rate until it is equal to the full unit strength.

- α_{ij} is the percentage of $A_i(t)$ that will engage an j^{th} type opposing force. This parameter reflects among other things the state of moral in the unit and its level of training.

- σ_{ij} is the rate of fire of the weapon used by the i^{th} force against the j-type opposing force. This parameter incorporates the probability of target acquisition.

- p_{ij} is the probability of single shot kill by an i^{th} force weapon against a j^{th} force target. This parameter incorporates the probability of correct aim/launching, probability of correct weapon functioning, and the probability of a j^{th} force kill when the i^{th} force weapon functions correctly.

- $T_{ij}(t)$ is the number of i^{th} force targets exposed to j^{th} force weapons. This number depends on the type of operation undertaken by the i^{th} force (offensive, defensive, infiltration, etc.) and the type of j^{th} force weapon (direct fire, indirect fire, etc.). The values for $T_{ij}(t)$ are determined by the analysts and vary from one game setting to another.

b. Calculation of the attrition against the j^{th} force exacted by the i^{th} force. Define $M_{ij}(t)$ by

$$M_{ij}(t) = \min (\sigma_{ij} \epsilon_{ij} A_i(t), T_{ji}(t)).$$

This represents the rate of engagement that can be effected by the i^{th} force against the j^{th} force. The equation states that the number of engagements cannot exceed the number of available targets presented by the j^{th} force. The number of j^{th} force targets killed during the time interval t to t + t is given by

$$K_{ij}(t + \Delta t) = \int_{t}^{t+t} p_{ij} M_{ij} \, dt. \quad (*)$$

In the special case where $A_i(t) = S_i(t)$ and where $T_{ji}(t) = \sigma_{ij} \epsilon_{ij} A_i(t)$ for both of the opposing forces, the equation (*) is equivalent to the Lanchester equations of attrition under his square rule. Thus, the approach provides somewhat more sensitivity that the classical Lanchester equations while still retaining a consistency with them.

c. While it is beyond the scope of this study, there are additional possibilities for increasing the fidelity of the model by allowing the parameters ϵ_{ij}, σ_{ij}, and $T_{ij}(t)$ to vary with dynamic battle conditions.

For example, the percentage of available forces that will use their weapons not only depends on the units state of training and state of moral, but also depends on the amount of enemy fire the unit is receiving. Therefore, one might express $\epsilon_{ij}(t)$ as

$$\epsilon_{ij}(t) = \epsilon_{ij}^{(o)} \left[(m_{ij} + (1-m) \exp \left(-\sum_{j} (\gamma_j M_{ji}(t)) \right) \right]$$

where $\epsilon_{ij}^{(o)}$ is the maximum percentage that will engage, and m_{ij} is the minimum percentage that will engage. The parameter γ_j reflects the analyst's view of the relatitive effect of j^{th} force munitions on the engaged unit. The sum in the argument of the exponential function thus, represents the cumulative effect of all units against the unit under fire. Each of the parameters σ_{ij}, and $T_{ij}(t)$ could be handled in the same manner.

2. Hetrogeneous Opposing Forces. In this case, the homogeneous subforces of each side are compared pair-wise and treated as in paragraph 1. The analyst is required to determine what portion of a homogeneous force element is to be directed against the various opposing force homogeneous subelements. That is to say, that the available forced for one component of a force $A_i(t)$, must be subdivided into J parts, $A_{ij}(t)$ where j= 1, ...,J, where $A_{ij}(t)$ represents the part of $A_i(t)$ opposing the j^{th} component of the opposing force. Thus, the analyst is constrained to determine parameters λ_{ij} such that $\sum_j \lambda_{ij} = 1$ and such that $A_{ij}(t) = \lambda_{ij} A_i(t)$. Thus the kill experienced by the j^{th} component of the opposing force is

$$K_j(t+\Delta t) = {}_i K_{ji}(T+\Delta T)$$

where $K_{ji}(t+\Delta t)$ is the kill experienced by the j^{th} component of the opposing force at the hands of the i^{th} force component, and is determined by equation (*) in paragraph 1. In that equation, $M_{ij}(t)$ is determined by

$$M_{ij}(t) = \min (\sigma_{ij} \epsilon_{ij} A_{ij}(t), T_{ji}(t)).$$

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ANNEX 3: A candidate Structure for the McClintic Theater Model.

1. Playing Elements.

a. Direct Combat Elements

(1) Infantry Battalion

(2) Armor Battalion

(3) Armored Cavalry Squadron

(4) Attack Helecopter

b. Combat Support Elements

(1) Artillery Battalion (listed seperately by weapon type)

(2) Close Air Support Aircraft

(3) Interdiction Aircraft

(4) Naval Combat Vessel

(5) Irregular Force Unit (guerilla operations)

(6) Electronic Warfare Element

- Direction Finding Air Craft/ Direction Finding Ground Unit

c. Combat Sustaining Elements

(1) Logistic storing/transhipment Facilities

(2) Logistic Materials by type of material. Units in Battalion Size consumption units.

(3) Transportation Battalion

(4) Internal Battalion Transportation Elements (Material Consuming Bn's)

(5) Maintenance Units: Direct Support Units and General Support Units.

(6) Sealift Vessel

(7) AAirlift Aircraft/Helecopter

(8) Engineer Battalion

d. Force Preserving Elements

(1) Army Air Defense Fire Unit

(2) Combat Air Patrol Aircraft

(3) Defensive Counter Air Aircraft

(4) Escort Aircraft

(5) Electronic Warfare Element, jamming or Deceptive

2. Combat Factors

a. Lines of Communication

(1) Road Network: road quality and road capacity

(2) Communication systems

- Communications Nodes (Communications Centers, wirelessrelays, etc)

- Information flow capacities

b. Weather

(1) Visability factors

(2) Terrain impact factors

(3) Troop/Equipment impact factors

c. Terrain: Identify specific degrees of impassibility that are correlated to land traffic vehicles.

3. Weapon Effects: Each playing element has an effect that it causes against each other playing element. This degree of detail need be incorporated into the attrition formulas.

A DETAILED ANALYSIS OF THE MCCLINTIC THEATRE MODEL

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The rapid analytical capability of the McClintic Theatre Model (MTM) makes it attractive for use as a force planning and contingency force analysis tool. A prudent initial step prior to utilization of MTM by the Office of the Joint Chiefs of Staff (OJCS) is a detailed analysis of the internal operations and imbedded assumptions of the model. This research effort provides that analysis and focuses upon whether MTM performs the functions advertised and whether those functions are modeled using credible analytical techniques. This analysis did reveal certain easily amended modeling infidelities. The primary conclusion, however, is that MTM is an analytical tool which possesses considerable potential as a high-level planning and decision aid.

1. PURPOSE AND SCOPE OF MTM RESEARCH

y June 1981 the McClintic Theatre Model (MTM) was receiving widespread use and attention the Army analytical community. The Studies, Analysis, and Gaming Agency (SAGA), Office the Joint Chiefs of Staff (OJCS), was directed to conduct an independent evaluation of l and to investigate potential uses of MTM within OJCS. Major John Edwards, Department Mathematics, United States Military Academy, performed the latter tasking while on summer ternship with SAGA in June, 1981. Also on summer internship with SAGA in June, 1981, the thor was asked to perform the independent evaluation of MTM. This report summarizes that prehensive analysis of the methodology, structure, and algorithms of MTM.

The rapid analytical capability of the McClintic Theatre Model (MTM) makes it attractive r use as a force planning and contengency force analysis tool. A prudent initial step ior to utilization of MTM by OJCS is a detailed analysis of the internal operations and bedded assumptions of the model. This research effort provides that analysis and focuses on whether MTM performs the functions advertised and whether those functions are modeled ing credible analytical techniques.

The scope of this research was to digest available MTM documentation and previous MTM aluations, interview Mr. McClintic and observe operation of MTM at the Army War College, ercise the SAGA version of MTM on a current contingency scenario and on smaller test enarios, and analyze in depth the software which models key MTM functions.

It is important to note the dynamic nature of MTM. Having become operational in 1980, MTM a very young model which is undergoing rapid refinement in response to needs expressed users of the model. This research effort addresses the MTM version which was operational SAGA in June 1981. Although the model's basic structure and operation remain unchanged, ere have been numerous modeling enhancements since June, 1981. The author, where possi-e, has added comments regarding these later enhancements.

2. OVERALL EVALUATION OF MTM

The conclusion of this investigative effort is that the McClintic Theatre Model (MTM) is analytical tool which possesses considerable potential as a high-level planning and deci-on aid.

The brilliance of MTM lies in the top-down, modular structure which allows for many unique rengths such as ease of operation, rapid execution of time, adaptability to new require-nts, and minimal data preparation time. Given these strengths, MTM is a particularly feasible tool for quickly identifying feasible alternatives in a planning or operational enario.

sent difficulty, easily amended over time, is the oversimplistic modeling techniques
ed within certain MTM subroutines. Annexes A through H contain an analysis and re-
ed modification of some of the key MTM subroutines. Annex I contains a summary of
odifications which will eliminate many of the difficulties. These current modeling
ities, however, should not overshadow the superb modeling and analysis performed
by Mr. McClintic and other analysts at the Army War College. As resources permit,
ular subroutines in which deficiencies exist can be refined.

ANNEX A - MTM METHODOLOGY AND ORGANIZATION

l is a hybrid analytic/simulation/wargame combat model. As such, certain combat func-
re depicted by mathematical equations (analytic) whereas others are represented by
son of random numbers with assigned probabilities (simulation). Additionally, the
g decision makers are afforded active participation in the conduct of the conflict
ia).

TM was designed by Mr. Fred McClintic at the Army War College (AWC) in 1980. The
l objectives for development of the model were to enhance the AWC wargaming curriculum
assist with the AWC Tactical Command Readiness Program. Additionally, MTM found
se in the Army Chief of Staff's Contingency Planning Seminar in November 1980. Since
ime MTM has been utilized by numerous DOD analytical agencies and operational units
ing the Strategic Studies Institute (SSI), Readiness Command and Rapid Deployment
(REDCOM, RDJTF), North Atlantic Treaty Organization (NATO), U.S. Army Europe
UR), and other agencies included in Figure 1.

M T M
(McCLINTIC THEATRE MODEL)

★ HYBRID { ANALYTIC / SIMULATION / WARGAME } COMBAT MODEL

★ YOUNG, DYNAMIC MODEL

MR. FRED McCLINTIC AWC 1980

★ MTM USERS

- AWC (TACTICAL COMMAND READINESS, CURRICULUM)
- CSA (CONTINGENCY PLANNING SEMINAR, NOV 80)
- VII CORPS (COLD REASON, APR 81)
- REDCOM/RDF (JUL 81)
- SSI (PARAMETRIC FORCE ANALYSIS STUDY)
- NATO (GENEVA PROTOCOLS)
- SAGA •TREM •USMA(UNIVAC) •CASMA •CAA •OTHERS?

★ EVALUATION OF MTM

EXCELLENT COMPUTER ARCHITECTURE

NEEDS SOME MODELING REFINEMENTS

VALUABLE TOOL W/ NUMEROUS USES

Figure 1.

RECOMMENDATION	REFERENCE
Make unit thresholds mission dependent.	Annex D Section I.B2
Convert from threshhold to breakpoint terminology.	Annex D Section I.B1
Include close air support and interdiction dependencies upon target vulnerability and weapon lethality.	Annex E Section I.C
Use metric convention with all distance measures.	Annex A Section II.A
Allow for free form input to FIRST data initialization routine. (accomplished since June 1981)	Annex A Section II.C
Include additional terrain/barrier effects in MTM.	Annex A Section II.D
Include force training/efficiency descriptor for each unit.	Annex A Section III.
Continue efforts to complement MTM with state-of-the-art graphics.	Annex C Section IV.

mentation/Implementation of MTM Modifications. A. Because of the numerous ad- of MTM, there are many "customers" who desire to use the model. This is a mixed Certainly, the use and critique of MTM by numerous DOD elements are helpful in ement of the model. On the other hand, care must be taken to insure that such y does not degrade the model because of failure to maintain necessary model docu- r or failure to implement modifications in a systematic and beneficial manner. An meeting, to be attended by the numerous users of MTM throughout DOD, has been d for June 1982 at the Army War College. Continuing user liaison of this nature oved MTM documentation is essential for orderly expansion of the MTM endeavor.

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S. Army War College, McClintic Theatre Model (U), Vol I (War Game Director's Manual), July 1981.

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S. Army War College, McClintic Theatre Model (U).

Graphics Capabilities. A. MTM is designed to be compatible with certain useful computer graphics technologies. The Army War College has experimented with graphic tablets on which to input orders (rather than using terminals). These worked well, but were not large enough to cover the entire theatre area of operations. Thus, their use has been curtailed for the time being. If larger graphic tablets could be obtained, this mode of operation would be preferable.

A one-color graphics program which prints out all terrain and barrier information has been very helpful in visualizing the terrain and identifying data base errors.

A multi-color graphics program has been developed for the APPLE micro computer, but size of the symbols is too large to permit display of a large sector.

The Army War College and other MTM users recognize the value of graphic capabilities and continue to investigate their feasibility. MTM, in particular, is a model which would be greatly enhanced by linkage with state-of-the-art graphics.

ANNEX H - ADDITIONAL MTM FUNCTIONS

Annexes A through G present those functions of MTM which were investigated in great detail. As stated in Section III, Annex A, MTM purports to model numerous other combat functions. Rather than misrepresent or unfairly criticize MTM in those areas, reference is made to the current MTM documentation, References 1 through 3.

It is anticipated that close scrutiny of these other MTM functions will reveal the need for refinements similar in nature to those already suggested. For example, the nuclear and chemical routines (which depict this aspect of the battle in a very general, parametric use) will undoubtedly need revision to accommodate scenarios requiring greater sensitivity to nuclear and chemical issues. Fortunately, MTM seems to easily adapt to such requirements.

ANNEX I - CONSOLIDATION OF MTM RECOMMENDATIONS

Current Army War College MTM Improvement Plan. The current Army War College (AWC) MTM model improvement plan obtained from Mr. McClintic, consists of the following desired modifications:

A. Ownership of minefields by RED or BLUE forces (currently a unit has no ability to pass through a friendly minefield).
B. Separate arrays for minefields, contamination, etc.; instead of packing into the TER array.
C. Combat Multipliers for flanking operations.
D. Scramble Defensive Counterair (DCA) aircraft to engage penetrating aircraft.
E. DCA over a unit (aircraft carriers).

MTM Recommendations. A summary of the MTM recommendations resulting from this investigative effort are catalogued below:

	RECOMMENDATION	REFERENCE
A.	Inclusion of capability for user to input macro or micro routing instructions.	Annex C Section II.C
B.	Parametrically address routing conflicts and transport system degradation.	Annex C Section II.D
C.	Utilize adversary dependent attrition factors.	Annex D Section I.B
D.	Tune the current attrition equations by altering the attrition factor, rather than increasing the battle time.	Annex D Section I.D
E.	Conduct additional research on attrition equations. In either case, insure that boundary conditions (annihilation and disparate force levels) are properly dealt with.	Annex D Section I.E and F
F.	Make Artillery assessments sensitive to the vulnerability of the target engaged.	Annex D Section I.G1
G.	Make artillery assessments sensitive to the lethality of the munitions used.	Annex D Section I.G4

not depict logistics in a realistic fashion, but at least it emphasizes the importance
s constraints of logistics upon combat operations.

ne only aspect of "maintenance" depicted in MTM is a parametric treatment of aircraft
ability. In actuality, this represents the availability component of RAM. The main-
ce and reliability components are not impeded.

nhanced Sustainability Version of MTM. MTM is currently being prepared for a Readiness
nd (REDCOM) exercise in late July. In response to REDCOM requests, five classes of
y, additional RAM considerations, and more realistic resupply operations are being
to MTM. The more realistic resupply operations will include transportation capacity
raints, partial simulation of a resupply network, and cross-leveling of supplies be-
units. These REDCOM additions will greatly enhance MTM's sensitivity to logistic
derations and may be included as a permanent addition to MTM or as a modular insert for
n analyzing logistics issues. This determination will be made following completion of
EDCOM exercise.

ANNEX G - MTM INTERFACE WITH THE USER

Many of the interfaces between MTM and the user have been discussed in previous annexes.
aspect of MTM is so unique, however, that it deserves separate attention. MTM is ex-
ly user friendly. This quality allows the user to wrestle with the substantive issues
e wargame, rather than with complex manual gaming rules or intimidating computer in-
ctions.

Input into MTM. A. The input of initial data into MTM was described in Annex B.

During the conduct of a wargame, input of orders into MTM is performed interactively.
will query the user for information and the user will respond with certain key words
as MOVE, FIRE, etc. A complete listing of these key words is in Reference 2. Inter-
y, MTM writes this input on the appropriate INBLU or INRED file, periodically scans this
t file, and uses IF statements to direct execution to the appropriate orders subroutine.

The controller can also enter numerous commands in MTM. By typing HELP, he receives a
of these commands.

Output from MTM. A. MTM periodically returns intelligence to the players. This in-
igence is either generated by MTM because of combat actions (movement, attrition, etc.)
y the player (request for the battle time, situation report, etc.). This output to
ers is stored on appropriate OTBLU and OTRED files as it is generated by MTM. It is
printed on the players terminal at the designated time in the battle. This out-file
cture also provides a valuable RESTART capability.

The MTM RESTART capability allows the game to be stopped and continued later with the
battle situation. It is also a good protection against system crashes. This restart
bility was used effectively during the test scenario runs. Internally, the current
U, OTRED, selected unit attributes, and unit locations are saved into the permanent
every 6 minutes of actual time.

At the end of a wargame, MTM utilizes data which has been collected in TALLY to compute
ures of effectiveness (MOEs). The MOEs which TALLY currently computes are as follows:

1. square miles vs time
2. strength remaining vs time
3. % initial strength vs time
4. aircraft remaining vs time
5. # of battles initiated (initiative)
6. % of forces uncommitted (flexibility)

tionally, a complete readout of unit statuses is provided.

MTM uses the standard WWMCCS graphics package, GIPSY, to display the MOEs graphically
histograms, pie charts, graphs, etc.

A modification currently being programmed by Mr. McClintic is to allow for dynamic ob-
ation of results. This would allow the controller to obtain statistical data and graph-
output during the course of the wargame, rather than at the end. This will be a valu-
contribution to MTM.

capability until it can reorient itself in the direction of the attack. This modification represents an important improvement to MTM. The ease with which the modification can be made attests to the flexibility of MTM.

ANNEX E

I. MTM Air Combat Modeling

A. This annex addresses the modeling of air assets and air defense assets in MTM. Analysis of these elements is abbreviated because the air related subroutines in MTM are currently undergoing a major revision. The original McClintic model did not play the air battle to a sufficient degree of detail. The current revisions will correct numerous deficiencies in the air battle. Subsequent paragraphs will address MTM air battle (as amended)and will withhold evaluations of those revisions until the process is completed.

B. Air-to-air Engagements. Air-to-air combat is portrayed by fighter aircraft with the missions of combat air patrol (CAP), defensive counterair (DCA), or escort (ESC). All fighters are assigned to units with CAP, DCA, or ESC missions. CAP units patrol a large area and intersect penetrating aircraft with a small percentage of their combat power. DCA units defend specific sites and, under the revision, scramble their aircraft to combat incoming hostile aircraft. This will require the incorporation of detection functions, intercept calculation equations, and endgame considerations (probably of detect/hit/kill) into MTM.

C. Air-to-surface Engagements. 1. Close air support and interdiction are modeled in a fashion similar to artillery. Each type of aircraft has a lethality parameter which determines the amount of attrition to be uniformly applied to all units in the target hex. The comments of Annex E, Section C, regarding munition and target vulnerability dependencies apply here as well.

2. Another interaction between air and ground elements is aerial reconnaissance (RECCE). When an aircraft overflies a hex containing enemy units, the RECON subroutine draws a random number and compares it with a specified detection probability. If the random number exceeds the probability; the ground unit is detected, the unit's size as estimated (using the same random number), and this information is transmitted to the appropriate commander.

3. Two other factors are being included by Mr. McClintic in the current air battle revision. First of all, secondary target opportunities are being included for all aircraft. Secondly, a queueing system for air orders is being instituted to allow air orders to accumulate and be executed as aircraft become available.

D. Surface-to-Air Engagements. 1. MTM probablistically attrites aircraft overflying a hex occupied by hostile units. This attrition is uniform regardless of the type of unit overflown. This is the only type of air defense function modeled by MTM and is most akin to ground fire from small arms.

2. MTM does not simulate the use of air defense artillery (ADA) assets. To do this, MTM must assign a much greater lethality against aircraft to ADA units and extend the area of influence outside of the hex to reflect the proper detection and engagements ranges of an ADA unit. This MTM inability to play ADA assets is a significant shortcoming and has limited MTM's applicability to current scenarios, particularly in the Middle East where modeling of Syrian SAM sites is central to the analysis. It is recommended that this modeling of ADA in MTM be given a high priority.

E. Lift Assets. MTM models helicopter and transport aircraft life assets. This function was not investigated in depth. A brief description is contained in Reference 1.

ANNEX F

I. MTM Substantiability Considerations

A. Current Version of MTM. The current vision of MTM depicts three classes of supply (POL, Ammo, and other) and maintenance to a limited degree.

1. The three classes of supply are stockpiled at a hypothetical depot. Each unit also possesses a basic load of supplies which are reduced by movement, combat, and time. Units failing to respond properly experience movement, combat, and time. Units failing to resupply properly experience movement and combat power degradations. The present MTM

G. MTM Artillery Assessment. 1. As mentioned in Section I.A. of this annex, artillery uniformly attrits all units in its target hex. More specifically, MTM will first insure that range and ammunition constraints are satisfied. If so, MTM "fires" the artillery from an artillery unit to a target at a specified time for a specified number of volleys. An immediate fire order experiences a 15 minute delay until execution of the first volley and a 1 minute delay between subsequent volleys. MTM flexibility allows for easy variation of these time delay factors.

2. There are several results produced by artillery impacting in the target hex. First of all, all units in that hex are attrited uniformly according to an artillery lethality parameter assigned to each artillery unit. The parameter designates the fraction of its combat strength that would be attrited by one full volley impacting on a unit in the target hex.

3. It is recommended that the artillery assessment procedures be modified in two ways. First, artillery impacting on a heterogeneous group of units does not in reality attrit all units in that group equally. Some units are obviously more vulnerable to artillery than are others. As MTM exists now, an ammunition depot and an armor unit suffer the same level of attrition from like artillery attacks. There are several techniques which could correct this difficulty in MTM. One feasible approach is the expansion of the artillery lethality parameter into a vector which reflects the lethality of that type of artillery against different types of units or different target vulnerability categories.

4. The second recommended modification to the MTM artillery assessment routine involves weapon lethality consideration. At present, MTM does not consider the type of ammunition fired by the artillery. Laser guided projectiles, conventional high explosive munitions, and smoke rounds affect the targeted unit differently. Present technology does not afford the luxury of modeling them all the same. Consequently, the lethality of artillery volleys should be gauged according to the type of munition used. This consideration expands the lethality vector (mentioned above) into a lethality matrix which provides a value for each target/munitions combination.

5. MTM also delays all moving units impacted by artillery for a specified time. The current delay time is 20 minutes.

H. Withdrawal/Threshholds. 1. MTM requires units to withdraw from a battle when they are attrited to a threshhold level. A unit threshhold is defined by MTM to mean the fraction of casualties that a unit/commander is willing to suffer prior to withdrawal. Threshhold is the mathematical complement of the more familiar term, breakpoint. Breakpoint is defined as the level of attrition at which the unit/commander will be forced to withdraw. The MTM unit threshhold values are entered by the user when exercising the ancillary MTM Data Base Preparation Program. Red or Blue Commanders may selectively change unit threshholds during the course of a MTM run. Threshhold values, when not preempted by user input, are initialized as follows:

Special Opn Unit	.9
Air Force Unit	.1
All other Units	.5

2. Historically, combat modeling breakpoint (or threshhold) values have been observed to be mission dependent. The majority of today's combat models recognize this fact and assign different unit threshholds for different unit missions. Since MTM does not assign missions to units, accommodation of this factor in MTM is not straightforward. It is recommended, however, that MTM address the mission dependent threshhold issue by lowering a unit's threshhold (raising its breakpoint) as it acquires more time in a hex, thus depicting its increased defensive posture.

3. A cosmetic change which would make the model more "user friendly" for the decisionmaker is conversion to the more familiar and intuitive breakpoint terminology.

I. Multiple Unit Engagements in MTM. Attrition calculations become more complex as more than two units become involved in a battle. Questions such as a "who fights who?" quickly arise. To handle this situation, MTM simply sums the combat values for all RED and all BLUE units involved in the battle. It then performs the attrition computations with these aggregate combat values. This approach is appropriate for a model such as MTM.

J. Flanking Movements/Unit Orientation. In response to recommendations from corps commanders, Mr. McClintic is presently modifying MTM to account for the possibility of flanking movements. To do this he is including a unit orientation parameter. Utilizing this parameter a unit which is attacked on a flank or from the rear will experience degraded combat

ANNEX D

I. MTM Land Combat Modeling

A. MTM depicts land combat using a low resolution firepower score approach. Battle is enjoined when two adversaries occupy the same hex or adjacent hexes. Based upon the relative combat weights of the opposing units, MTM decrements each unit periodically to reflect battle attrition. The battle ends when one of the units is forced to withdraw because of the attrition of a specified percentage of its original strength. Artillery, also a source of attrition in the land battle, uniformly attrits all units in its target hex. Other factors, to be discussed, similarly degrade the combat value of affected units. The above synopsis of land combat modeling in MTM will be expanded in subsequent paragraphs.

B. The combat values utilized in MTM are merely quantitative assessments of a unit's capability to wage combat against the enemy. Any number of different firepower score conventions (WEI/WUVs, for instance) are useable in the MTM attrition formulas. At present MTM cannot accommodate combat value dependencies upon unit or mission type. Regarding dependency upon unit type, consider the situation in which "unnatural adversaries" such as artillery and armor wage combat at close ranges. In this case, the armor shock action and invulnerability to direct fire artillery would dictate different levels and rates of attrition than with more conventional combat, such as armor against armor. Similarly, close combat between artillery and dismounted infantry would result in different levels and rates of attrition on both sides. These examples illustrate a definite unit type dependency in attrition calculations which should be modeled appropriately. To do this in MTM would require storage of adversary dependent attrition rate coefficients for each unit. Considering the small number of unit types in MTM, this modification would not significantly degrade execution time or memory requirements. For those familiar with Lanchester models of combat, this change would establish a heterogeneous attrition capability in lieu of the present homogeneous technique.

C. As mentioned above, mission type dependencies are also not portrayed by MTM. For example, combat between an attacker and a defender of equal strengths will generally result in much higher attrition of the attacker. Thus, a unit's attrition rate is dependent upon its mission. MTM does not assign missions to units. Consequently, MTM cannot explicitly model this dependency, but does increase a unit's combat power according to the time it has occupied the hex affected by the battle. This technique, given proper tuning of its parameters, appears to be satisfactory.

D. As mentioned earlier, MTM decrements each unit peridoically to reflect battle attrition. To do this MTM utilizes the following attrition formula:

$$\frac{\%\ \text{friendly loss}}{2\ \text{hours}} = \left\{1 - \frac{\text{friendly value} - .03(\text{enemy value})}{\text{friendly value}}\right\} * 100\% \qquad (3)$$

This simplifies to the relationship,

$$\frac{\frac{dF}{dt}}{F} = \frac{-.03\ E}{F} \qquad (4)$$

which is observed to be the familiar Lanchester Square Law:

$$\frac{dF}{dt} = .03\ E \quad \text{and, conversely,} \quad \frac{dE}{dt} = .03\ F.$$

E. The Lanchester attrition rate coefficient (.03 casualties/firer/2 hours) value was arrived at through the use of Delphi techniques which tapped the military expertise of numerous senior Army commanders. The attrition equations originally represented 2 losses per one-half hour but currently utilize a two hour increment which reflects a lower rate of attrition. Mr. McClintic states that the time increment, rather than the magnitude of the coefficient, was changed to reflect a more realistic combat reporting situation (battle reports from subordinate units every 2 hours rather than every 30 minutes). Unfortunately, this increase in the battle time step will allow forces to suffer attrition beyond the time that they would normally be withdrawn from battle. A preferred approach to tuning the attrition rates would be to adjust the .03 factor.

F. An additional attrition rate coefficient consideration is that the attrition rate is probably not equal for both sides. Furthermore, a given side would display different coefficients for its different force members (armor, infantry, artillery, etc.). These issues, previously discussed in I.B. and I.C., should be researched further.

another at maximum unit speed and does not consider any of the impeded movement factors.

4. The MTM routing mechanism is proper in light of the purpose and nature of MTM. Exact determination of the best movement path would be possible through the use of a shortest path algorithm (such as Djikstra's), but such an algorithm would seriously bog down MTM and is not recommended.

C. Calculation of Distances in MTM. 1. The calculation of distances between MTM hexes takes into account proper trigonometric relationships. The following formula is utilized to calculate the distance between the centers of two hexes with coordinates (EW2, NS2) and (EW1, NS1):

$$\text{HOWFAR} = \text{AVGHEX} * \sqrt{(75.)(EW2-EW1)^2 + \left[\frac{(NS2-NS1)}{2}\right]^2} \qquad (1)$$

The term under the square root sign is an application of the Pythagorean theorem, $a^2 + b^2 = c^2$, and calculates the distance in hex units from origin to destination. Examination of the hex terrain structure reveals that the North-South (NS) distance between adjacent hex centers is greater than the East-West (EW) distance between adjacent hex centers. Thus, the EW displacement is multiplied by a factor of .866 (Note: (.866) = .75). Note that the NS column of hexes contains only odd or even numbers (as explained in Annex B).

2. The AVGHEX term in equation (1) adjusts for the differences in north-south hex dimensions related to proximity to the equator. The following AVGHEX equation properly performs this adjustment by calculating the average hexsize:

$$\text{AVGHEX} = \frac{\text{HEXSIZ(Big Map)} + \text{HEXSIZ(Detail Map)}}{2} \qquad (2)$$

D. MTM does not currently possess the capability to specify microscopic or macroscopic routes for moving units. The user may input his desire to move a unit to a certain destination, but may not specify which hexes will be traversed en route. Secondly, the user may not input a string of successive destinations to depict a macro-movement plan. It is recommended that MTM be modified to allow for specification of these routes by the user. This modification would not be costly in terms of memory allocation, execution time, or programming skills; and would provide a more realistic command environment for the user.

E. Resolution of routing conflicts is not depicted in MTM. Two units utilizing the same route do not impede each other's movement rate. In actuality, the priority unit would be allowed to move while the nonpriority unit would experience degraded movement or none at all. Another situation presenting demands upon the transportation system is refugee traffic. The impact of MTM's current inability to address routing conflicts is difficult to ascertain. At a minimum, the result is overly optimistic movement rates when multiple unit moves on the same route are considered.

F. Degradation of the transportation system over time is not depicted in MTM. In actuality, avenues of advance do have limited capacities which degrade over time. Mechanized unit commanders would certainly attest to the importance of this consideration. In the lengthy scenarios addressed by MTM, this factor should be addressed at least parametrically.

II. Recommendations/Conclusions (Movement)

A. The general approach towards movement in MTM is realistic in light of the purpose and nature of MTM. To enable MTM to be fast-running, easy to use, and global in scale; MTM depicts movement in a gross fashion using the approximations discussed. Other more resolute models depict movement of units through road networks composed of nodes and arcs, across actual terrain data, or both. Movement can be modeled with greater fidelity using this approach, but such an approach with MTM would be prohibitive with respect to computer storage space, running time constraints, and ease of operation. Thus, the current movement modeling approach should be retained and refined as addressed below.

B. It is recommended that MTM be modified to allow micro and macro routing specifications by the user (as discussed in I.D.).

C. It is recommended that MTM address routing conflicts and transportation system degradation in a parametric fashion (as discussed in I.E. and F.).

SUBROUTINE	PARAMETER	VALUE
INTORD	Time delay between requesting and receiving HUMINT on a hex.	1 hour
ENGR	Tonnage of other supplies required to emplace minefield	1 ton
MANEUVER	Damage to a unit for entering a minefield,	3%
	nuclear-contaminated hex	10%
	chem or bio-contaminated hex	25%
MANEUVER	Delay caused to moving units for entering a minefield	Random number between 2-4 hrs.
	nuclear-contaminated hex	$\frac{(.5 \text{ to } 1.5)*\text{HEXSIZ}}{10}$
	chem or bio-contaminated hex	$\frac{(2 \text{ to } 4)*\text{HEXSIZ}}{10}$
National Intel	Blue probability of detection	75%
	identification	75%
	Red probability of detection	75%
	identification	75%
	Interval between National Intelligence reports	
	Blue	12 hours
	Red	12 hours
	Time delay of detection to theater commander	
	Blue	1 hour
	Red	2 hours
AIR	Aircraft availability first 3 days	80%
	after 3 days	60%
AIRGND	Time between unit sorties for mission planning, rearming and refueling	1 hour
	Damage to target per aircraft sortie	Varies with A/C type
	Delay to target due to air attack	15 minutes
AIRDEF	Damage to aircraft passing over enemy unit	
	clear day	5%
	night or adverse weather	3%
FIRESPT	Time between volleys on same target	3 min./tube artillery 6 hrs./rockets or missiles

ANNEX C

I. *Movement Functions in MTM*

A. As noted in the data structure explanation (Annex B), MTM does not explicitly model a conventional road network with nodes and arcs. Movement is not conducted along roads or avenues of advance, but rather from hex to hex. Specifically, a variable called TJUMP specifies when a unit will "jump" from its present hex to its next hex. In accordance with the timing mechanisms detailed in Annex A, MTM periodically compares TJUMP with the battle time, BTIME. If TJUMP is less than BTIME, then the movement to the next hex and TJUMP are calculated and stored for the following jump.

B. MTM Routing Mechanism. 1. Inherent in this movement process is the routing mechanism. To determine movement paths, MTM uses a shortest path approximation technique. This approximation combines the impeded movement time to move out of the present hex and into an adjacent hex with the unimpeded movement time from that adjacent hex to the final destination hex. This calculation is performed for all hexes adjacent to the current hex. The adjacent hex rendering the smallest approximate movement time (BEST) is designated as the next hex. This procedure is performed for each jump until the unit reaches its destination hex. The impeded movement time takes into consideration movement constraints such as day/night, weather, maximum unit speed, hex terrain composition, and presence of barriers. The unimpeded movement time is merely the time to traverse a straight line distance from one hex to

THRESHHOLD, % acceptable casualties (50%)
MAX SPEED, cross country (15.0 kmph)
SUPPLY STATUS, 10 classes, 3A, 5A (999. short tons)
MAX CARRY CAPACITY (8000. short tons)

Air Force, artillery, missile, and naval gun units also possess:

PERCENT DAMAGE, per full strength volley (1%)
RANGE, max (16. miles)

Air Force Units also possess:

NUMBER OF AIRCRAFT (72)
TYPE OF AIRCRAFT (F-4)
AIR SPEED (700-knots)

B. The unit representation methodology used in MTM is acceptable. Each descriptor is represented in memory by a separate storage vector which contains a particular descriptor value for every unit being played. For example, the SPEED vector looks as follows:

SPEED (Unit 1, Unit 2, ..., Unit 300).

(MTM is currently dimensioned for a maximum of 300 units.)

C. The unit strength (POINTS) and threshhold (THRES) variables attempt to describe the fighting capability of a unit. Discussions with DIA analysts indicate that a third factor describing a unit's state of training should be included to properly describe and compare units. Additionally, expansion of the unit descriptor's should include lethality and vulnerability considerations. This will be discussed in Annex D, Modeling of Land Combat.

D. Additional unit descriptors can easily be included. For example, Mr. McClintic has recently included a unit orientation descriptor which allows for differentiation between frontal and flanking actions.

IV. Additional Data Requirements

A. Additional data requirements, extracted with permission from MTM Documentation (Reference 3), are as follows:

FACTOR, ratio of battle time to real time
% BLUE/RED COMMO JAMMED
PROBABILITY OF RAIN, each 6 hour period of day
PROBABILITY OF FOG, each 6 hour period of day
SUNRISE/SUNSET
PROBABILITY OF DETECTION, by aircraft under day/night, clear/snow, fog/rain conditions
AMMO/POL CONSUMPTION RATES
  Tons of ammo per full strength artillery volley
  Tons of POL per hex moved by a unit
  Tons of POL per aircraft sortie
  Tons of ammo per aircraft sortie which fires
HEX SIZE - in miles
DEPOT SUPPLIES - Tonnage of each class of supplies (POL, ammo, and other) in Red and Blue theater supply depots.
NUCLEAR AND CHEMICAL PERMISSIONS - Initial permission granted or not granted for Red and Blue forces.

B. There are certain data assumptions imbedded in the model which can be changed by MTM programmers as better data becomes available. These embedded factors, extracted with permission from Reference 3, are as follows:

SUBROUTINE	PARAMETER	VALUE
EWAR	Percent of radio message traffic intercepted:	
	Blue	5%
	Red	5%
FIRORD	Time delay between requesting and receiving artillery fire	15 minutes

C. As mentioned, each hex also has a barrier code associated with it. Input to FIRST is similar to the terrain input. FIRST then builds a BAR array for input into MTM. Each hex barrier code has six digits, one digit being associated with each side of the hex. The convention used represents the North side by the 1st digit continues clockwise sequentially.

For example, a barrier code 111311. indicates that the south hex boundary has a code of 3, while all other sides have a code of 1. Barrier codes currently utilized by MTM are as follows:

1 - No Barrier	4 - Road
2 - River	8 - AT Ditch
3 - Bridged River	9 - Impassable

All hexes not specified are initialized with a barrier code of 111111.

D. The only effect that these terrain and barrier codes play in MTM is to degrade or facilitate movement through the use of movement factors associated with each code value. As Noted in Annex I, Mr. McClintic plans to unpack the barrier codes to allow for better resolution and easier manipulation of those values. Additionally, it is recommended that the effect of terrain and barriers on other combat functions besides movement may be considered. For example, the effect of artillery in a wooded hex is different from in a clear hex. Similarly, the elevation of a mountainous hex affects the capabilities of units in adjacent non-mountainous hexes. Therefore, inclusion of MTM of appropriate resolution terrain influences should be investigated.

E. The hexes are combined to form overlays for existing maps of appropriate scale. A hex coordinate system assigns letters to east-west positions and numbers to north-south positions. Thus, designation of the location of a hex consists of a letter/number combination. A complete description of this map terminology is contained in Reference 2.

Note that each column of hexes contains only odd or even numbers. Consequently, numerous encode and decode operations are necessary to convert from hex terminology to the TKR and BAR array locations.

F. The hex composition described above is contained in the "detail map." MTM also possesses a "big map." Whereas the detail map usually represents a theatre level area of operations, the big map represents a much larger geographic sector which encompasses the detail map. Big map hexes represent a significantly larger area than the more resolute detail map hexes.

G. With respect to computer storage, the TKR array currently has 41 columns and a variable number of rows dependent upon the size of the big map. These rows are partitioned with 1 through 54 representing the detail map and rows above that represent the big map. When performing computations involving both big map and detail map coordinates, conversion routines (BIGSML and SMLBIG) are utilized.

H. The big map/detail map concept is superb. It allows for gaming of long distance sustainability and employment considerations while concurrent theatre operations are being conducted.

II. Although MTM has been primarily used to model theatre level operations, there is no inherent reason why greater resolution hexes with correspondingly resolute units could not be represented. At the extreme, the hexes could be 10 meters across instead of 10 miles across with an individual soldier representation rather than a division or corps unit representation. Certainly care must be exercised to insure that the modeling algorithms (particularly attrition) remain appropriate for the unit resolution, but the variable resolution feature of MTM does enhance the spectrum of applications. For instance, a fast-running MTM with high resolution could provide excellent "sand table" training for small unit commanders.

III. A. Unit representation data requirements for MTM are explained fully in Reference 1. Essentially, every unit on the battlefield will possess the following descriptors (examples given in parentheses):

ID (BLUE, #48)
TYPE (MECHANIZED)
NAME (3RD US INF(M) DIV)
SIZE (US DIV)
POSITION (AA 59)
STRENGTH, relative (6.0)

VII. As mentioned, a ratio between battle time and real time is used to determine how much to increment battle time. This ratio is input by the controller who can change it at any time. By changing the ratio, the controller can adjust the time pressure on the RED and BLUE teams, speed up during periods of inactivity to minimize player idle time, and slow down during time of major combat to allow for more thorough command and staff actions.

ANNEX B - MTM DATA REQUIREMENTS AND STRUCTURE

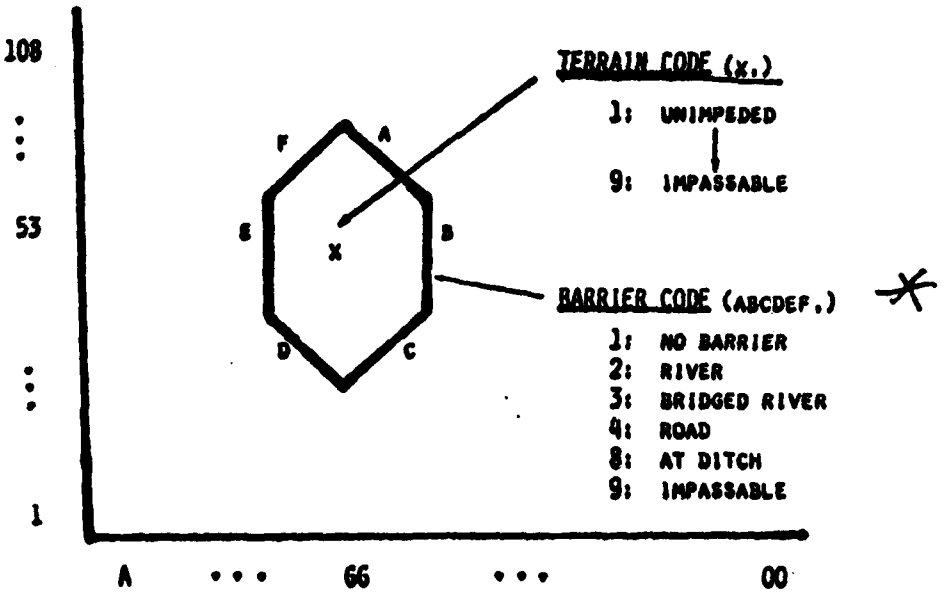
1. Data Input

A. As mentioned previously, MTM possesses an ancillary data base building program (termed FIRST) which greatly facilitates construction of the data base. FIRST interactively questions the user regarding the terrain, barrier, unit, and other miscellaneous data which is needed to operate MTM. FIRST then encodes these user inputs in various ways and constructs data files which will be used by MTM. If one desires to exercise a previously constructed data base, use of FIRST is not necessary.

B. Each hex has a terrain code and a barrier code associated with it. See Figure 4 for a graphic depiction of the MTM Terrain Representation. The terrain code is a one digit number representing the terrain classification of that particular hex. For ease of input, FIRST allows the user to enter a particular code followed by all hexes with that value. FIRST then builds a TRR array (each cell representing a hex) which is used by MTM. Terrain codes are currently user defined with an unimpeded movement hex classified as 1. Other terrain code values are related to the amount of movement degradation experienced in crossing that hex.

All hexes not specified are initialized with a terrain code of 1.0.

MTM TERRAIN REPRESENTATION



★ VARIABLE HEX RESOLUTION

★ DETAIL MAP/BIG MAP

Figure 4.

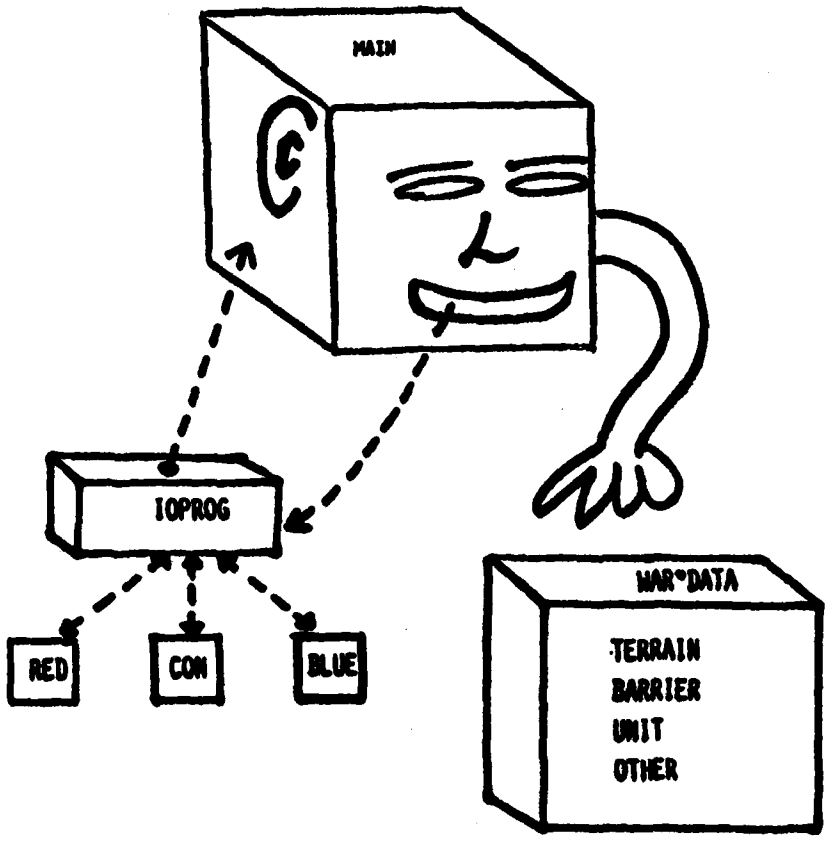
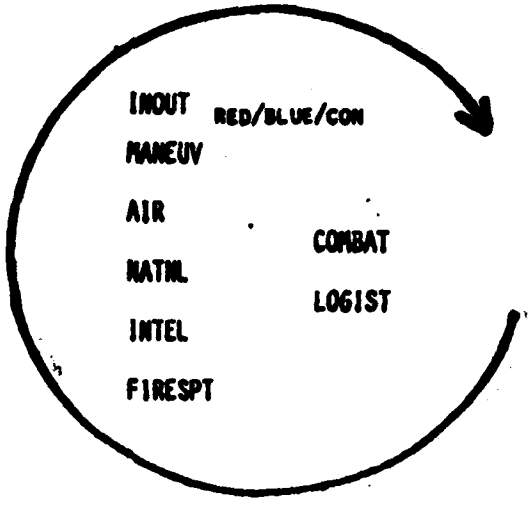


Figure 2.

MTM TIMING MECHANISM

(FACTOR=___)



THE VALUE OF FACTOR DETERMINES THE REAL TIME/BATTLE TIME RATIO.

★ BY CHANGING FACTOR, THE CONTROLLER CAN "SPEED UP/SLOW DOWN" MTM.

Figure 3.

Close Air Support (CAS), Interdiction, Air Base Attack, and Reconnaissance missions are all modeled by MTM. To model surge rate, aircraft availability is held at 80% for the first 3 days of combat, and it falls to 60% thereafter. Air-to-ground, ground-to-air, and air-to-air combat are simulated for every air mission. The capability to attack roads and bridges to limit enemy maneuver is built into the model.

Artillery fire from Army and Navy guns is simulated. The maximum range of the fire support unit is checked to make sure the weapons can reach the target coordinates before the mission is fired. If the target is beyond the range of the weapon, the order is ignored and the requesting commander is so informed. If the firing unit does not have sufficient ammunition, it fires until it runs out, and the commander is informed that it has stopped firing because of a lack of ammunition. A 15-minute delay between requesting artillery fire and receiving the first round on the target is assumed. A 3-minute delay between volleys on the same target is assumed for tube artillery, and it takes 6 hours to reload missile and rocket launchers. These numbers can easily be changed within the model. If an artillery unit is given a new mission before it has completed the previous mission, it starts firing on the new target after it completes the current mission. Surface-to-surface missiles and rockets are treated the same as artillery, but with a longer maximum range, different percent damage per volley, and a longer time between volleys.

Nuclear, biological, and chemical weapon capabilities are built into MTM. Permission for each side to use nuclear or biological and chemical weapons must be granted by the war game controllers by using the control subroutine. If a force calls for a nuclear or biological and chemical attack on a specified coordinate, and permission has been granted by the controllers, the attack execution time is a function of the delivery means (aircraft, artillery, missile, etc.). Use of dirty or persistent nuclear or chemical rounds contaminates that hex for a certain length of time; however, noncontaminating rounds may be specified in the order, in which case, no contamination results. Both forces are notified that a nuclear or chemical and biological weapon has been detonated in the specified hex. Any unit entering a contaminated hex will suffer a predetermined percent loss and a significant time delay enroute through the hex. Every hour that a unit remains in a contaminated hex will result in additional losses.

IV. MTM consists of a main program (MAIN) consisting of 56 subroutines and functions, an input/output program (IOPROG) which allows simultaneous input/receipt of information of red, blue, and controller participants; a data base (WAR*DATA) which contains terrain, barrier, unit and miscellaneous information; and an ancillary data base building program (FIRST). Figure 2 depicts the relationships among these major MTM components.

V. A unique advantage of MTM MAIN is its timing mechanism. A common type of simulation is a time-step simulation in which time jumps by a certain amount, all of the battle functions are performed, time jumps another step, and so on. MTM differs from this approach and uses a time-driven technique.

In MTM's time-driven technique, time is incremented (Subroutine INCRET) within reach of the major subroutines depicted in Section 8 of the flowchart. For instance, when the COMBAT subroutine is called, COMBAT in turn calls INCRET to update the battle time (BTIME). INCRET, in turn, finds out what the actual time is and increments battle time by an amount calculated using the current ratio of battle time to real time. Then the COMBAT subroutine is exercised to resolve all outstanding attrition related calculations. The program then exits the COMBAT subroutine and enters the LOGIST subroutine, which utilizes INCRET to increment the battle time again. MTM MAIN will sequentially proceed through all of the subroutines until COMBAT is entered again and all attrition calculation requirements occurring since the last entrance into COMBAT will be performed. Many other subroutines will be utilized by the ones shown in Figure 3. For example, the MANEUVER nesting is as follows:

```
MANEUVER
      INCRET
      MOVNXT
        TRAFFIC
        ROWPAK
           BIGSML
           SML.BIG
```

VI. The communication flow between MTM and the players occurs continuously. This is a unique advantage of MTM facilitated by the IOPROG file manipulation arrangement. Many war-games use next-event procedures in which users can only enter orders during certain phases.

III. MODEL OVERVIEW (extracted with permission from Reference 1). The McClintic Theatre Model was developed around the diagram shown in Figure A - Theater Commander's Interface. The items circled in Figure A are included in MTM. Those not circled are not yet simulated by the model, but could be added as the model evolves. The paragraphs below examine each of the functional systems in Figure A starting with the maneuver system and going clockwise. Both the capabilities and the limitations of MTM are covered in this section.

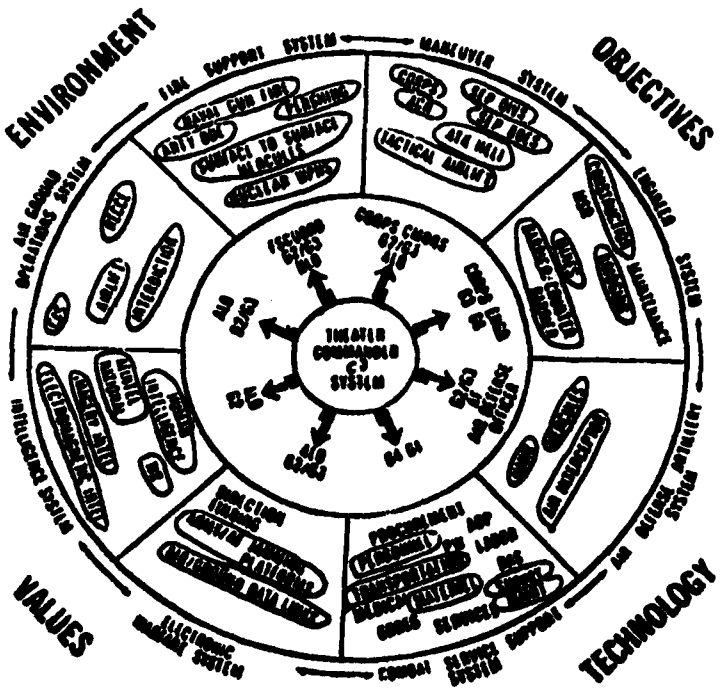


Figure A.

Under the maneuver system, any size ground combat unit may be handled by the model. Part of the data input for each unit is its maximum movement speed. When a unit is told to move from point A to point B, any movement speed up to and including its maximum movement speed may be specified. If no speed is specified in the order, or if the specified speed is greater than the unit's maximum speed, the unit is moved as fast as possible. Terrain and barriers affect all ground movements. Terrain such as mountains, forests, and cities slow movement by any factor specified in the input data. Some mountains may be more of an obstacle than others. Barriers such as rivers, bridged rivers, antitank ditches, and minefields degrade movement also. Up to nine types of barriers may be defined by the input data. Roads are treated as barriers which actually speed up movement rather than impede it. In addition to ground combat units, naval and air units of any size from a single vessel or aircraft up to fleets or wings can be maneuvered by MTM. Attack helicopters and tactical airlift are included in the model. Also utility helicopters and transport aircraft are permitted to airlift or airdrop units. And, Navy units can sealift ground units. Any battle effect not explicitly accounted for can be manually implemented by the control subroutine which can pick up a unit and put it down anywhere on the map, or inflict any amount of damage on any unit.

Minefields and the clearing of minefields are modeled by MTM. Minefields can be emplaced in any hex that has a ground unit with sufficient supplies to emplace mines, provided that unit is not currently engaged in ground combat. Also, fixed-wing aircraft, helicopters, and Navy units can emplace minefields. Artillery-emplaced mines are not currently in the model, but can be manually simulated by using the control subroutine to instantly emplace minefields anywhere on the map. Roads and bridges are part of the data inputs; they can be destroyed by aircraft and artillery in order to slow the enemy's movement. Control can also add new roads or bridges.

AN ANALYSIS OF

MTM COMBAT SUBROUTINE

Cadet Mark D [illegible]

United States Military Academy

20 May 1983

CONTENTS

Purpose And Scope of MVP Research

Since its creation, the Moslintic Theatre Model (MTM) has received widespread use and attention throughout the Army. In response to a written request from the Commandant , US Army War College (24 November 1982), the Model Validation Program (MVP) has been instituted at the United States Military Academy. The primary purpose of MVP is to assist the Army War College in providing model users with "confidence statements" about the outcomes obtained from those models.

At the United States Military Academy, the MVP will be based on two concurrent research efforts. One effort, conducted by the Department of History will focus upon the historical confidence of MTM. The second effort is being conducted by the Department of Engineering which is addressing the statistical confidence of MTM.

The purpose of this project is to examine the combat subroutine. The examination has focused upon two areas of the combat subroutine. The first area is the descriptive aspect of the subroutine. This has included the development of the heuristics for the subroutine and the determination of the inputs and outputs of the subroutine to be analyzed. The second area of attention was the analysis of the subroutine through regression techniques. Also, through this analysis, a foundation and basic framework for the analysis of Army models in the Model Validation Program as requested by the Army War College has been established.

RESULTS

The results of the research are divided into the two areas of analysis. The first results are the descriptive aspects of the combat subroutine. A major step in the analysis of the combat subroutine was the creation of the flow chart for the subroutine. At this time it is believed that this is the first flow chart of any of the numerous subroutines used in MTM. The flow chart is contained in Annex A.

The flow charting of the subroutine has provided insights into the inputs used in the resolution of combat in MTM. Key factors which help determine the results of the combat include the supply level of the unit in combat, whether a unit is stalled in a mined or contaminated hex, or whether a unit is out of FOL. The major factors which effect the results of combat are the terrain which a unit occupies and the time the unit has been in that location.

Also, the flow charting of the subroutine has raised some important questions concerning the parameters which are used in the subroutine in order to resolve combat. A unit will enter the combat subroutine with an amount of points which reflect the unit's strength. The points are then multiplied by a CMULT factor which is dependent upon the time, terrain, and other factors mentioned above. The value of the CMULT factor is what raises the questions. Why is the CMULT factor .5 for a unit being out of FOL and what impact does it have on the results? What impact does the time a unit is in position have on combat results and what impact do the CMULT factors play? Why are the CMULT factors for Red and Blue forces different for the same time in a position? These questions, though out of the scope of

this project, need to be addressed in further analysis and sensitivity analysis. Sensitivity analysis should also be conducted on the attrition rate coefficients used in the equations to calculate losses. These equations are based on the Lanchester square laws.

The second aspect of the research was the analysis of the combat subroutine outputs. This portion of the study resulted in two accomplishments. First, a methodology has been established which can be used in further studies in the Model Validation Program. The methodology includes the creation of additional subroutines which capture data points for the factors being studied. These subroutines are inserted around the combat subroutine to capture the data coming into the combat model and to capture the results coming out of the subroutine. A copy of "INCOMBT", the subroutine that captures data coming into the combat subroutine, is contained in Annex B. In order for this subroutine to work several other changes to the model had to occur. First the main subroutine had to open the data files which are written by the "INCOMBT" and "OTCOMBT" subroutines. Second, the main subroutine had to run the "INCOMBT" subroutine. The control subroutine also had to be changed in order that the new data files would be accessible after they were written. And also the UNIVAC computer system had to be adjusted to accept additional data files for the MIM model.

Next, once the data files were generated, a method for analysis using SPSS was established. This includes the writing of an SPSS program and obtaining initial outputs.

The second accomplishment was the initial results obtained from the SPSS package. These results, contained in Annex C, indicate that the combat subroutine results are what should be expected.

Summary

The research conducted as an initial step in the MVR has resulted in the following:

a) Flow charting of the combat subroutine raising questions concerning parameters.

b) An established methodology for further research for the MVR.

c) Initial results obtained from analysis of combat.

d) MVR researchers guide for further analysis. (Annex J)

The flow chart for the combat subroutine is not an all encompassing chart, nor does it attempt to define all the variables within the subroutine. Rather, the flow chart is a simple guide to aid the user as to the processes and major factors which drive the resulting combat.

On the first page of the flow chart, the key factor to notice is that combat resolution is accomplished every two hours. Apparently, this timing factor is a mechanism used to achieve what is thought to be a realistic rate of attrition and combat.

The next key factors that should be analysed are found on page three of the flow chart. The first is the terrain factor. Below is a table which shows the terrain factor and its corresponding CMULT factor, which is used in determining the strength of the units for battle.

Terrain factor	CMULT factor
$0 > x$	.5
$0 \leq x$	1.0
$2 \leq x$	2.0
$3 \leq x$	3.0

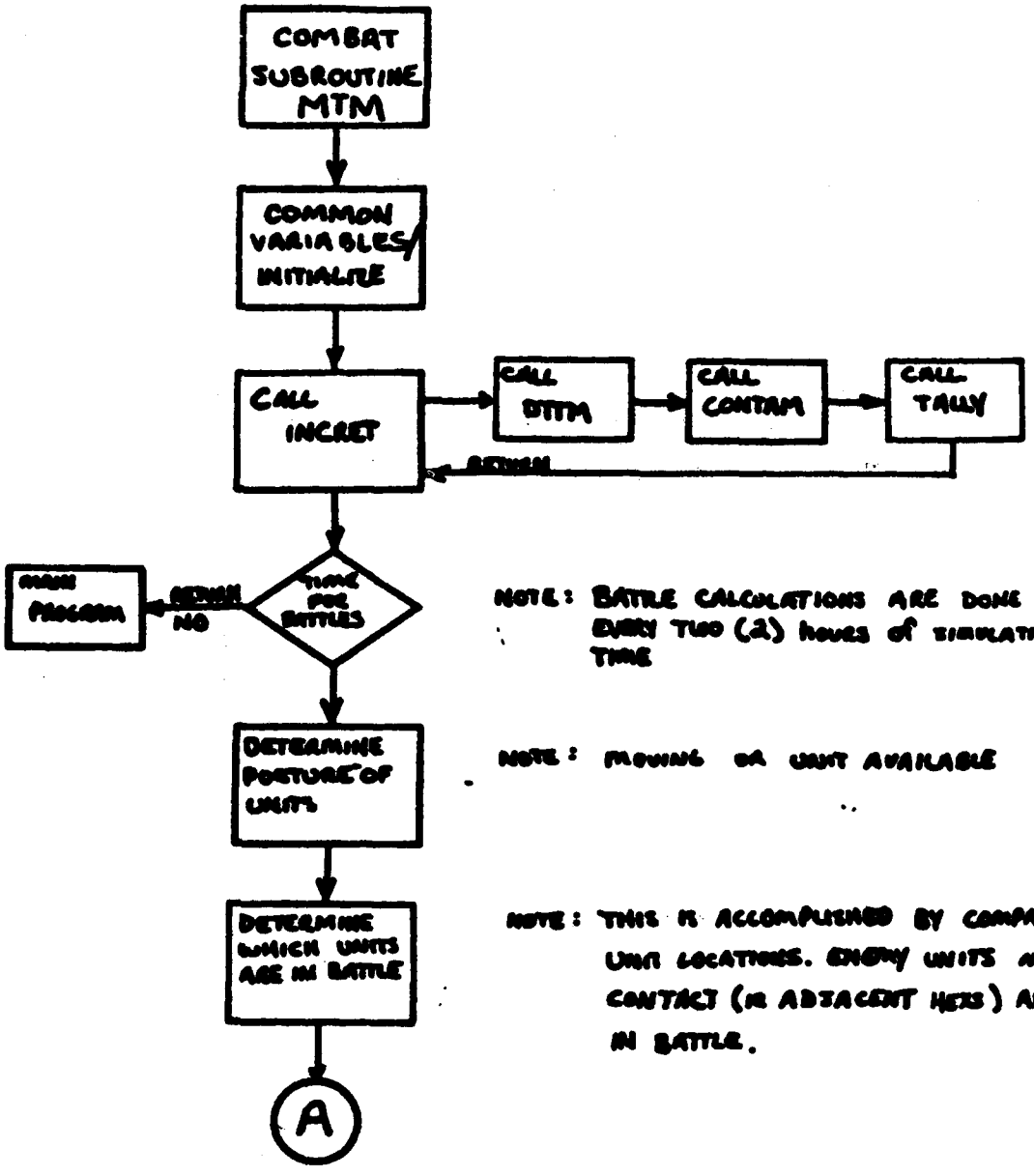
Next, if a unit is stalled in a hex, then the CMULT factor is reduced 60%. And if a unit is out of POL, then the CMULT factor is reduced by 50%.

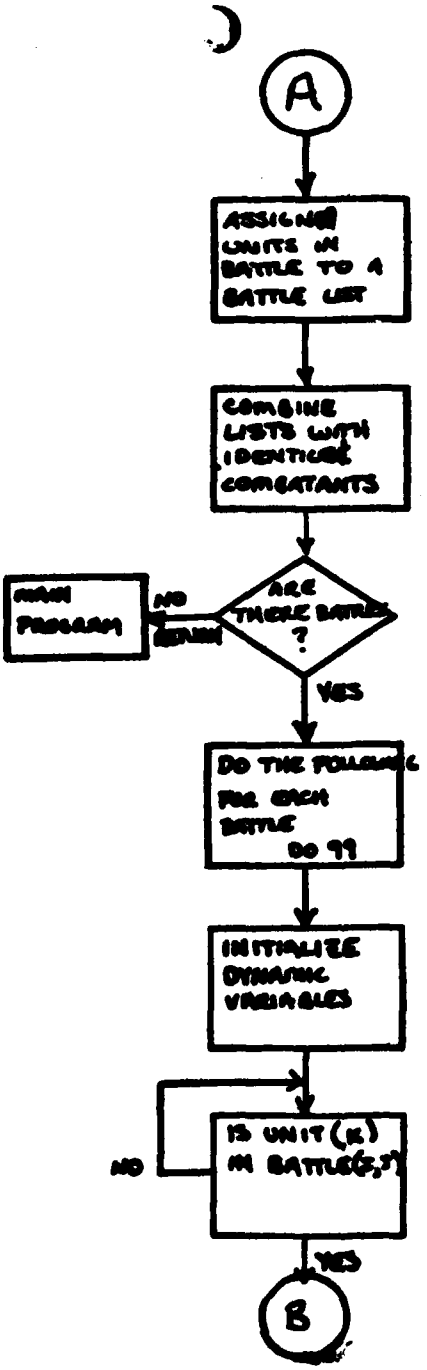
Another key factor is the time a unit is in position. Notice on the flow chart that these CMULT factors for time in position differ for the red and blue teams. This may be an effort to model a strength in the red teams ability to construct defensive positions.

The last page of the flow chart illustrates two other points that should be considered. First is that the time in position for both sides is an aver-

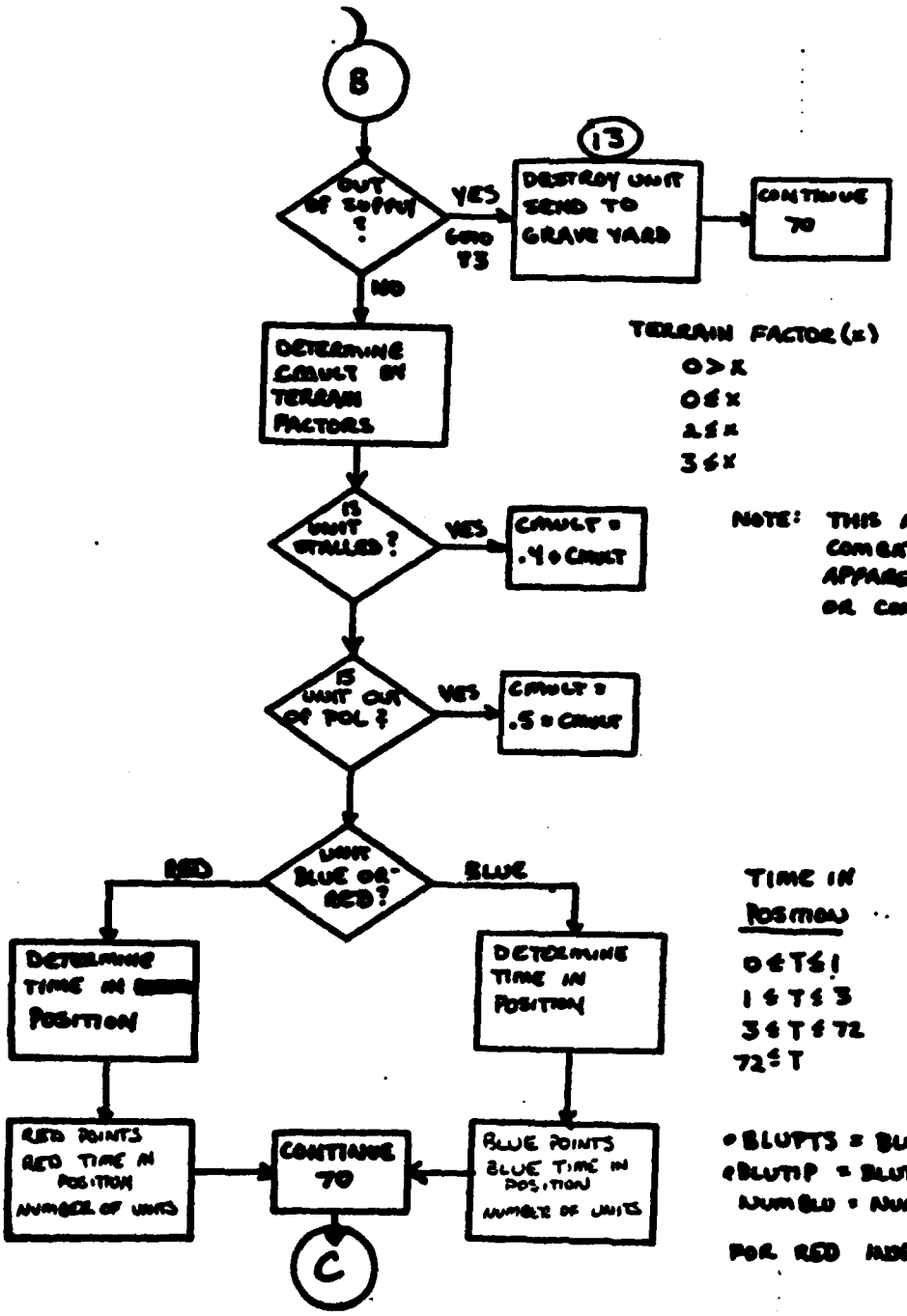
age for all the units on the same side involved in that specific battle.

Secondly, the equations used to determine the losses for both sides are listed on the last page of the flow chart. These equations are based on the Lanchester square law. The importance of these equations is the constant attrition coefficients assigned a value of .05.


COMBAT SUBROUTINE MTM
COMMON VARIABLES/ INITIALIZE
CALL INCRET
CALL DITM
CALL CONTAM
CALL TALLY
RETURN
MAIN PROGRAM
RETURN NO
TIME FOR BATTLES
DETERMINE POSTURE OF UNITS
DETERMINE WHICH UNITS ARE IN BATTLE
A
NOTE: BATTLE CALCULATIONS ARE DONE EVERY TWO (2) HOURS OF SIMULATION TIME
NOTE: MOVING OR UNIT AVAILABLE
NOTE: THIS IS ACCOMPLISHED BY COMPARING UNIT LOCATIONS. ENEMY UNITS IN CONTACT (IN ADJACENT HEXS) ARE IN BATTLE.



NOTE : THIS IS DONE BY A NESTED DO LOOP # 70, # 61



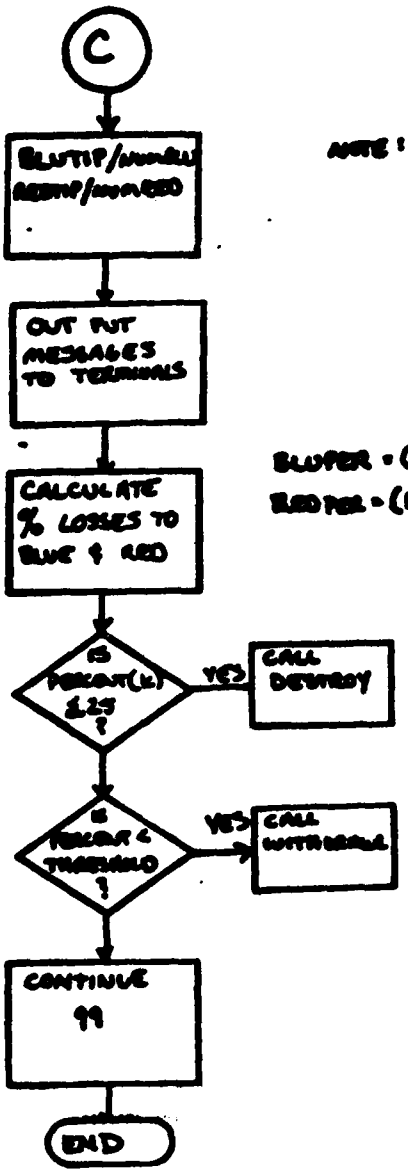
TERRAIN FACTOR (X)	CMULT
0 > X	.5
0 ≤ X	1.0
2 ≤ X	2.0
3 ≤ X	3.0

NOTE: THIS A REDUCTION IN COMBAT POWER APPARENTLY FOR MINES OR CONTAMINATED HEX

TIME IN POSITION	CMULT = X RED	BLUE
0 ≤ T ≤ 1	X = 1.0	1.0
1 ≤ T ≤ 3	1.5	1.0
3 ≤ T ≤ 72	3.0	1.5
72 ≤ T	3.0	3.0

* BLUPTS = BLUPTS + CMULT * POINTS(X)
* BLUTIP = BLUTIP + BCLOCK - ARTIME(X)
NUMBLU = NUMBLU + 1

FOR RED INSERT 'RED' FOR 'BLU'



NOTE: BLUTIP AND REDTIP ARE AVERAGE FOR ALL UNITS INVOLVED IN THIS BATTLE

BLUPER = (1.0 - (BLUPTS - .03 * REDPTS)/BLUPTS) * 100

REDPER = (1.0 - (REDPTS - .03 * BLUPTS/REDPTS) * 100

ANNEX E

Annex E is a copy of the subroutine INCMBT. This subroutine was written to capture any data points coming into the combat subroutine and write these data points to a separate data file. The first portion of the subroutine is the common block. The subroutine only writes the information to the data file for those units that are in combat.

The data file number for INCMBT is 31. The Univac system will now allow up to 36 data file structures to be attached to MAIN.

The subroutine that captures data points coming out of the combat subroutine is called OTCMBT. This subroutine is called from the combat subroutine. The only difference between INCMBT and OTCMBT is that OTCMBT writes to another data file.

There is one problem with the OTCMBT subroutine that may be easily corrected which time did not permit beforehand. Simply move the call statement prior to the statements calling subroutines destroyed or withdraw. This will create a data file identical to the file created by INCMBT.

```
)BROUTINE INCMBT
)RAMETER  NBU=300, NSP=12
)MMON /TERAIN/ TER(41,82), BAR(41,82), BARIER(9)
)MMON /UNIT/NUNIT(NBU),NAME(NBU),UNITTP(NBU),UNITCL(NBU),EW(NBU),
)S(NBU),ARTIME(NBU),PERCNT(NBU),POINTS(NBU),SPEEDX(NBU),
)OSTUR(NBU),EWDEST(NBU),NSDEST(NBU),TJUMP(NBU),EWNEXT(NBU),
)SNEXT(NBU),SPEED(NBU),NUMVOL(NBU),RANGE(NBU),WARN(NBU),
)SEAD(NBU),ATYPE(NBU),ESCORT(NBU),THRES(NBU),AIRSPD(NBU),
)UBTYP(NBU),SIZE(NBU),TOEPER(NBU),PERSON(NBU),CARRY(NBU),
)UPPLY(NBU,NSP),AIRCFT(NBU),DAMVOL(NBU),TFIRE(NBU),EWFIRE(NBU),
)SFIRE(NBU),ORIENT(NBU)
)MMON/OTHER/NUMBER,ASTIME,FACTOR,SUNRIS,SUNSET,BCLOCK,EWJAMB,
)WJAMB,EWINTR,EWINTB,POLCON,POLSOK,ANTCOR,ANGVOL,BATTIM,NBATL,
)UCBLU,NUCRED,ICHEMB,ICHEMR,DAYNIT,WX,WXFACT,UNITME,PROB(4),
)RAIN(4),PDDCLR,PDDFOG,PDDRAN,PDNCLR,PDNFOG,PDNRAN,TRACE,
)IMEL,TIMLST,TIMLOG,BLUNAT,REDNAT,BNATIN,BNATD,BNATPD,BNATPI,
)NATPA,RNATIN,RNATD,RNATPD,RNATPI,RNATPA,HEXSIZ(144),NBINIT,
)RTALY(30),NUCH,EWCHG,NSCHG,UNITCH,IDLECL(12),MOVECL(12),
)ODECL(12),COMBCL(12)

)ARACTER*2 EW,EWDEST,EWFIRE,EWNEXT,EWCHG,ORIENT
)ARACTER*4 UNITCL,DAYNIT,ATTACK
)ARACTER*5 SUBTYP,SIZE
)ARACTER*7 ATYPE
)ARACTER*8 WX
)ARACTER*10 UNITTP,POSTUR
)ARACTER*18 NAME
)TEGER  BATTLE(30,30), ESCORT, NCOMBT(30)
)GICAL WARN
) 50 K=1,NBU
 (BCLOCK.LT.BATTIM) GOTO 99
 (POSTUR(K).NE.'COMBAT    ') GOTO 50
)ITE(31,10) NUNIT(K),UNITCL(K),POINTS(K),PERCNT(K),AIRCFT(K)
)ITE(31,12) DAMVOL(K),NEW(EW(K)),NS(K),NEW(EWDEST(K)),NSDEST(K)
)ITE(31,11)BCLOCK,ARTIME(K)
)RMAT(I5,A5,3F7.0)
)RMAT(F7.0,4I5)
)RMAT(2F5.0)
)NTINUE
:TURN
)D
```

licit assumption in the MTM figures is that the unit would in contact for the entire period and not withdraw at a rmined threshold value. As can be seen, if attrition is to continue for equivalent time periods, MTM actually attrits ter force more rapidly. The basic SAGA comment is still valid, re research and validation is required on the attrition and parameters of MTM.

Make artillery assessments sensitive to the vulnerability target engaged. No change.

Make artillery assessments sensitive to the lethality of ltions used. No change.

Make unit thresholds mission dependent. The thresholds in WG are not mission dependent. As in MTM, time in a hex is used it the advantage of the defender. The AWCWG has incorporated threshold decrement due to time in combat. The threshold is ically raised 5% for every 24 hours in combat. The threshold reduced by taking a unit out of combat for rest and recuperation.

Convert from threshold to breakpoint terminology. No change.

Include close air support and interdiction dependencies upon vulnerability and weapon lethality. No change.

Use metric convention with all distance measurements. This has been accomplished in the AWCWG.

Allow free form input to FIRST data initiatization routine. WG has made great strides in improving the user friendliness of re model. Both unit and terrain data bases are input from a ven display which is self-explanatory and extremely easy to use. l also incorporates several consistency checks on the input data insure correctness before the actual wargame will run. The portion of the wargame is also very user friendly with a menu nteraction with the player. Once the player selects the type nd or action he wishes to input, that command is displayed ill in the blank format.

Include additional terrain/barrier effects in MTM. Listed e the terrain and barrier effects modeled in MTM and the AWCWG:

	Combat Multiplier		Movement Rate Multiplier	
	MTM	AWCWG	MTM	AWCWG
	1.0	1.0	1.0	1.0
	2.0	1.5	0.5	0.0625
	3.0	1.10 Small	0.33	0.95
		1.25 Medium		0.85
		1.5 Large		0.25
s	3.0	1.5	0.2	0.0625

. Conduct additional research on attrition equations, in either nsure that boundary conditions (annihilation and disparate force) are properly dealt with. Below is an extract of the AWCWG 's Guide which details that attrition equation and parameters o model ground combat.

ound Attrition Formula. The outcome of combat is determined by the combat tios of the forces engaged and is expressed in attrition to each side % of loss to red and blue).

CR = Combat Ratio (Blue to Red or Red to Blue)

CRA = Combat Ratio Adjustment

$$CR(B) = \text{Combat Ratio for Blue} = \frac{\text{Red Combat Power}}{\text{Blue Combat Power}}$$

$$CR(R) = \text{Combat Ratio for Red} = \frac{\text{Blue Combat Power}}{\text{Red Combat Power}}$$

CRA = Combat Ratio Adjustment

FORMULA: Unit Loss = 1% X CR X CRA

AMPLE OF COMBAT RATIO ADJUSTMENT EFFECT ON % OF LOSS

CR	X	CRA	=	TOTAL LOSS IN %
1.0 : 1.0		1.0		1.0
1.25 : 1.0		1.25		1.55
1.5 : 1.0		1.5		2.25
2.0 : 1.0		2.0		4.0
3.0 : 1.0		3.0		9.0
4.0 : 1.0		4.0		16.0
5.0 : 1.0		5.0		25.0
6.0 : 1.0		6.0		36.0
7.0 : 1.0		9.0		63.0
8.0 : 1.0		9.0		72.0
9.0 : 1.0		9.0		81.0

ition to the total loss % above, the model generates a random which alters the total loss % by ± 2% of its value. The intention of the change in attrition modeling was to amplify trition rate in a disparate engagement of large forces against The above equation must be modified for the differences in time increments when comparing AWCWG and MTM attrition. Below me comparative results:

R	AWCWG Loss %	MTM Bde (6 hr) Loss	MTM Div (12 hr) Loss
0	1.0	8.73	16.7
0	2.25	13.2	25.7
0	9.0	26.7	52.7
0	36.0	53.7	100.0
0	81.0	80.7	100.0

B. Combat multipliers for flanking operations. This recommen-
n has been adopted in two instances by code and one by controller
vention. If a unit is moving and is attacked on the flank or
its combat strength is permanently reduced by 50%. If a unit
mbat is attacked from the rear, i.e. surrounded, its combat
gth is reduced by 50%. If a unit is attacked from the flank or
the controller can intervene and increase the combat strength
e attacking unit to portray the surprise and advantage of its
tion of attack.

C. Scramble Defensive Counterair (DCA) aircraft to engage
rating aircraft. The emphasis of the air war modeling in the
is considerably different than in MTM. MTM models a very
led individual aircraft war while AWCWG aggregates to the air
level. Specifically, a percentage of aircraft are allocated to
CA mission by the players. Every 24 hours of battle, the
t strength of attacking bombers and the DCA fighters are
to a homogeneous Lanchester Equation to determine how many
rs penetrated the DCA cover. The Lanchester parameters are
ntly adjusted so that evenly matched air units would suffer
attrition and an additional 3.75% of the bombers would be forced
vert from their mission. DCA is only computed for those bombers
king airfields. Combat Air Patrol aircraft are allocated and
ed in a similar manner. The CAP Lanchester parameters are
uch that, in an evenly matched battle, the bombers would suffer
ttrition and an additional 15% would be diverted.

D. DCA over a unit (aircraft carriers). As noted in the last
raph, CAP aircraft would assist in protecting an aircraft
er, however, DCA is currently only modeled for airfields.

E. Inclusion of capability for user to input macro or micro
ng instructions. No change.

F. Parametrically address routing conflicts and transport
n degradation. In the AWCWG, if two units move through the same
imultaneously, their movement rates are degraded by 75%. As the
moves units, it attempts to avoid moving two units simultaneously
gh the same hex. There is no parametric modeling of transport
n degradation.

G. Utilize adversary dependent attrition factors. The AWCWG
zes a homogeneous Lanchester Equation derivative which does not
iminate as to the types of adversary units in ground combat.
ir model does discriminate between fighters and bombers, but
stween types of each or weapons carried.

H. Tune the current attrition equations by altering the attrition
r, rather than increasing the battle time. Although the attrition
ion has been altered, the battle time increment problem has been
vated in the AWCWG. The battle time increment depends on the
al counter size: 3 hours for battalion, 6 hours for brigade, 12
for division, and 24 hours for corps. MTM increments every 2

DEPARTMENT OF ENGINEERING
UNITED STATES MILITARY ACADEMY
WEST POINT, NEW YORK 10996

-F 21 June 1983

RANDUM FOR RECORD

ECT: McClintic Theatre Model Enhancements in the US Army War College War Game

REFERENCES:
a. The Joint Chiefs of Staff, Studies, Analysis, and Gaming Agency, randum Subject: McClintic Theater Model, 28 Sep 81.

b. US Army War College, USAWC War Game Player's Guide (DRAFT), ay 83.

c. US Army War College, interview with CPT Steve Brannon, Information nology Division, 20 Jun 83.

PURPOSE: The purpose of this memorandum is two-fold, to detail those ncements made to the original version of the McClintic Theatre Model) in the USAWC War Game (AWCWG) as recommended in the 1981 Studies, ysis, and Gaming Agency (SAGA) memorandum and to comment on further ncements found in the AWCWG that should be considered for inclusion TM.

The AWCWG is a greatly revised version of the original MTM which was rporated into the AWC curriculum in 1982. The model has been acted, written in PASCAL, and placed on an ALTOS 8000-10 Micro- uter. Each section room at AWC is equipped with an ALTOS. The main ose of the AWCWG is to assist instruction in the operational level ar. The operational level of war encompasses strategic goals within eater of war and deals with large unit operations. As with each of MTM, the AWCWG has been tailored for instructional use at the ational level. Several of the enhancements, however, are pertinent ultiple levels and purposes of MTM usage. It must be noted that this ysis was accomplished without the availability of a computer code ing and is based on the above cited references. Due to the retical and operational nature of the analysis, the lack of specific uter code does not seem to be a detriment.

This paragraph will list the recommendations of the SAGA memorandum the AWCWG enhancements, if any, that pertain to the recommendation.

A. Ownership of minefields by RED or BLUE forces (currently a has no ability to pass through a friendly minefield(without ring casualties)). The AWCWG does model ownership of minefields. friendly unit crosses a hex with a friendly minefield, its rate ovement is slowed, but it does not suffer casualties due to the ield.

```
NAME          LOOK AT COMBAT
ABLE LIST     TIME,INPTA,INPERA,INPTB,INPERB,OTPTA,OTPERB
T FORMAT      FIXED(F4.0,1X,F2.0,1X,F4.0,1X,F2.0,1X,F4.0,1X,F2.0,1X,F3.0)
T MEDIUM      DISK
 CASES        UNKNOWN
TERGRAM       OTPERB WITH TIME
ONS           2,6,7
ISTICS        ALL
SH
ILE
```

An example SPSS program is on the following page.

To run an SPSS program the following procedure can be used.

PAGT ACG,A data file name

PAGT UNI S.,DATA FILE NAME

PAGT SPSS

When you run SPSS, the program will prompt you after the first line the program types. Type in the following:

CARD THE NAME OF THE SPSS PROGRAM

example: CARD X32655*X32655.100A

MAKING CHANGES TO MTM

To make changes to MTM, first access the subroutine you want to change or write the subroutine you want to add. Save the new subroutine or replace a changed subroutine. Then MTM must be re-compiled. To re-compile MTM type

ACTB to get into the EXEC mode

Then type

-START EX*MTM.COMPL

This re-compiles MTM and sends a copy of MTM to the printer on 1st floor Thayer Hall

After starting the COMPL subroutine, you may sign off the computer and the compilation will continue to run. Don't forget to pick up your copy of MTM!

SUBROUTINES

The different subroutines in the MTM program may be listed in one of two ways. Either type

LIST S,D MA*MTM.

or type

OLD MA*MTM.COMCL
LIST

All the work done on MTM should be done on the program

MA*MTM.

Also there are two subroutines that are not under MA*MTM. but under MA*M. These programs are the random number generator and ? .

RTM DATA FILES

The files existing for the analysis of combat subroutine are called

"IN*DATA."
"OT*DAT."

They may be accessed by typing

OLD(and the file name.)

Creating other data files

When creating other data files the files must be opened in the main subroutine

example: OPEN(UNIT=32,FILE='OT*DAT.',STATUS='OLD',ACCESS='SEQ')

The unit number may be from 1 to 36 but may not be the same number as another unit number for a data file.

The files must then be closed in the control subroutine

subroutine; "LA*RTM.CONTROL"

closing: CLOSE(UNIT=32)

STOPPING NIM

This procedure should be followed in order that the game is stopped and does not run all night even though you've signed off the terminals. Also this will allow you to access the data files without trouble, otherwise the files will not be closed properly. If you can not access the data files see the goldgoats.

To stop the Red and Blue terminals, simply type, in response to "Commander what is your command";

STOP

then sign off the terminals.

To sign off the control terminal type

STOPGM

This can be done twice just to make sure the game is stopped. Then type

STOP

and sign off the terminal.

RUNNING MTM

To run MTM you need three terminals, one for the Red team, one for the Blue team, and one for the controllers.

To start the MTM game, after signing on the computer type

```
xGTS
```

This gets you into the EXEC mode. Then type

```
@START EXT*MTM.RUN
```

This starts the game. Next in order to start the interaction of the players, on each terminal type

```
@xqt EXT*MTM.IOT.xOG
```

The program will then ask you which player will use this terminal. Next the program will ask if you want the communication file initialized? The first time the answer should be yes. If the computer crashes or kicks you off the system, you can restart the player terminals only this time you need not initialize the communication file.

At times the MTM game run will be put into the backlog of the system. A call to the gold coats in the main computer room of Thayer Hall can correct this. If orders were put into the terminals before the game is taken off the batch backlog, orders do not need to be retyped, rather the game should simply continue.

INDEX

ANNEX C

MTM RESEARCHER'S GUIDE

This guide is created to aid in the further research of MTM. It is not an exhaustive guide into the computer system nor does it contain every thing there is to know about MTM. Rather it is a compilation of the authors experiences into the running of MTM, how to make corrections and other insights into MTM research.

ANNEX C

This annex contains the initial results using SPSS to analyze data obtained from an actual MIM run. The data was of one unit and contained the essential data points of that unit as it proceeded through the combat subroutine and after the results of the subroutine were calculated.

The SPSS run looks at the percent of unit strength over time. The resulting scattergram for this unit is what is predicted by the Lanchester square law.

After the 50% attrition of this unit, the unit withdrew but was then immediately contacted by another, fresher enemy unit. Thus we see a greater attrition rate for the unit depicted.

This annex also illustrates the statistical analysis portion of the MVI, with which further analysis of the key parameters will be conducted.

Terrain/ Barrier	Combat Multiplier MTM	AWCWG	Movement Rate Multiplier MTM	AWCWG
Highway	1.0	1.0	3.0	3.0
Road	1.0	1.0	2.0	2.0
Bridge	1.0	1.0	2.0	1.25
River	1.0		0.5	12 hr delay if a bridge destroyed
Antitank Ditch	1.0		0.33	
Minefield	0.5		2-4 hr delay	
Nuclear Contamination	0.5		0.5-1.5 hr delay	
Chemical Contamination	0.5	.95 Red .9 Blue	2-4 hr delay	1 hr delay
Hills		1.25		0.5
Desert		1.25		0.5
Swamp		1.5		0.0625
Trail,Tunnel Pass		1.0		1.25

The blank entries above are elements not modeled. As can be seen, the AWCWG has increased the modeling of terrain effects. These effects are incorporated into the combat power scores which enter the ground combat attrition formulas, however, the effect of terrain on individual weapon types is not modeled. This will not be possible until the model uses heterogeneous Lanchester Equations.

R. Include force training/efficiency descriptor for each unit. No change.

S. Continue efforts to complement MTM with state-of-the-art graphics. No change.

5. There are several other enhancements within the AWCWG that should be considered in further analysis of MTM.

A. A unit suffers 1% attrition when it breaks contact.

B. The AWCWG models the linkage between combat units and their combat support and combat service support as they affect combat power. The player allocates support and service support assets to the combat units. The model then increases the combat power points of the combat unit proportionate to the support allocated. The player also defines Lines of Communication (LOC) for the support units to the combat unit. If these LOCs are interdicted or cut by enemy action, the combat power of the combat unit is decremented 24 hours later. If the support units come under ground attack, or when they displace, their support is stopped for a period of time. This linkage is crucial to modeling the deep interdiction tactics of Air Land Battle and the Warsaw Pact.

C. Units suffer 0.25% attrition for every 10 km of ground movement.

6. As can be seen from the above enhancements, the AWCWG seems to represent an improvement over MTM in modeling the operational level of war. The players' attention is focused more at the large unit level of decision making and less at the tactical level of smaller unit combat. Both models, however, appear weak in modeling the intelligence function. Significant research and modeling effort is required to define operational level intelligence requirements and to incorporate these into the theater/corps level model.

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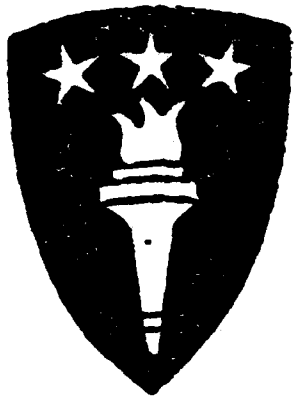

US ARMY WAR COLLEGE

UNITED STATES MILITARY ACADEMY

NEOLITHIC THEATER MODEL

VALIDATION PROGRAM

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D R A F T

MODEL VALIDATION PROGRAM 15 June 1983

DEPARTMENT OF ENGINEERING

OBJECTIVES AND ESSENTIAL ELEMENTS OF ANALYSIS(EEA)

OBJECTIVE 1. Develop a further understanding of the internal dynamics of the McClintic Theatre Model (MTM).

EEA 1A. What is the internal structure of MTM, including parameter values and mathmatical computations?

EEA 1B. What were the computer modeling weaknesses of the original MTM?

EEA 1C. What modeling improvements have been made in the various versions of MTM?

EEA 1D. What modeling improvements have been or should be made to the Honeywell version of MTM resident at USMA?

OBJECTIVE 2. Investigate the sensitivity of MTM output to key input parameters.

EEA 2A. How do input parameters mathematically relate to MTM output?

EEA 2B. Which input parameters are most significant to the output values?

EEA 2C. What factors within the model modify or utilize these significant input parameters?

EEA 2D. What is the source of the input parameters and how sensitive is the output to changes of these parameters?

EEA 2E. How do the input parameters and outputs, at subroutine and total model level, compare with those of other combat models resident at other Army analytic agencies?

EEA 2F. Which of the input parameter values, their relative significance, and resultant output values are not consistent with combat modeling precepts or military judgement?

OBJECTIVE 3. Assess the impact of the stochastic aspects of MTM upon the confidence which can be placed upon model results.

EEA 3A. What are the stochastic elements within the model?

EEA 3B. Are the stochastic elements correctly modeled and stochastic events correctly generated?

MTP Department of Engineering (Cont.)

EEA 3C. How do the stochastic elements effect the model results?

EEA 3D. Are the model results within a reasonable range based on the stochastic elements which effect them?

EEA 3E. How does human variability effect MTM results?

OBJECTIVE 4. Assist the use and interpretation of MTM output by using available technology to develop additional MTM post-game analysis techniques?

EEA 4A. What are the critical variables necessary for post-game analysis?

EEA 4B. How can computer statistical routines such as SPSS be used to gather and display outputs and variables for analysis?

EEA 4C. How can computer graphics be used to display outputs and variables for analysis?

DEPARTMENT OF HISTORY

OBJECTIVES AND ESSENTIAL ELEMENTS OF ANALYSIS(EEA)

OBJECTIVE 1. Address the fidelity of MTM with historical results through the MTM gaming of selected military battles.

EEA 1A. What are useful sources of historical data for use in MTM?

EEA 1B. What methodology was used to convert terrain and unit data into an MTM data base for the historical battles?

EEA 1C. How well did the MTM version at the Army War College replicate the 1973 Suez Crossing?

EEA 1D. How well did the MTM version at the Concepts Analysis Agency replicate the Falkland Islands battle?

EEA 1E. How well did MTM at USMA replicate the Battle of Karkov?

EEA 1F. How well did MTM at USMA replicate the Battle of the Bulge?

EEA 1G. Do the combat parameters within MTM appear correct from a historical perspective?

EEA 1H. In what areas of combat results does MTM replicate history?

EEA 1I. In what areas of combat results does MTM not replicate history and what appear to be the critical factors which contribute to the discrepancy?

EEA 2J. How does MTM compare with results experienced in the Quantified Judgment Model?

OBJECTIVE 2. Assess the usefulness of a computer wargame such as MTM as a tool for obtaining historical insight.

EEA 2A. What combat factors does the model indicate were most critical?

EEA 2B. Can the model facilitate the effects of changing battle events or factors?

EEA 2C. Does the model distinguish between the results of a good and a poor battle plan and execution?

JECTIVE 3. Explore the pedagogical applications of MTM within the Department of story.

EEA 3A. What modifications are required to FIRST, the data base building program, facilitate its use in historical analysis?

EEA 3B. What modifications are required to MTM to facilitate its use in storical analysis?

EEA 3C. What additional output media would facilitate historical analysis.

NOTE: Several other curricular aspects of MTM are being explored which do not ecessarily pertain to the MVP.

BJECTIVE 4. Identify shortfalls in the MTM battlefield environment or in the epiction of primary combat functions.

EEA 4A. What primary combat functions are not modeled within MTM?

EEA 4B. What primary combat functions within MTM appear to be unrealistically odeled?

EEA 4C. What combat results from MTM appear to be unrealistic?

EEA 4D. What levels of units does MTM model effectively?

An Analysis of Ground Combat Attrition in the McClintic Theater Model Plus

Introduction

(U) The McClintic Theater Model Plus is an interactive computer simulation of theater level warfare, designed for the analysis of operations orders and contingency plans. From the model, analysts can extract critical combat information, such as the extent to which the mission has been accomplished, manpower levels, and logistics consumption.

(U) For the analysts to be confident about the information that they are providing, they must be satisfied that the the model is a realistic simulation of theater level warfare. The developement of MTM+ has progressed to a point where the analysts feel confident in the ability of the model to simulate movement of forces by both ground and air, logistical resupply and barrier enplacement. Additionally, analysts can be confident of their ability to correctly extract the pertinent information from the model. The outcome of any computer simulated conflict is highly dependent on the method the model follows in attriting forces engaged in combat. It is combat attrition which determines the outcome of the factors that are of interest to the study's sponsors, and yet, it is in this area where the developers of MTM+ are least sure of the ability of the model to simulate reality. The purpose of this paper will

be to present and analyze the results of the algorithms modeling allocation and attrition of ground forces in MTM+. This report will not discuss other important causes of force attrition, such as mine warfare and air attacks. Due to their significant impact in MTM+, these algorithms should be studied to determine their applicability.

Procedure for Testing the Attrition Algorithm

(U) Testing of the attrition results from MTM+ was a four stage process. The first stage required a general familiarity with the entire model and a more detailed understanding of the allocation and attrition algorithms. The second stage was the developement of a process to isolate desired units, fight them in a controlled situation and obtain desired battle information. Thirdly, a number of representative engagements needed to be selected and run through the process. The final stage was an analysis of the results to determine their reasonableness.

Allocation and Attrition

(U) Allocation and attrition in MTM+ is based on a deterministic algorithm developed by Dr. Dennis DeRiggi. The implementation of this algorithm into the interactive wargame has some stochastic properties. Sample size studies were

performed and revealed that the stochastic effects were not great. There were additional changes from conception to code which did have a significant effect on the results; however, I will not discuss these, since the program will be modified to do away with the discrepencies.

(U) The algorithm is divided into two segments: allocation and attrition. The algorithm sees allocation as the problem of how a firer can partition its rounds of ammunition among the targets acquired. Each target has a point value that the firer earns if it kills the target. The firer also has a single shot kill probability (sskp) for each target. The algorithm maximizes the expected value of the number of points that the firer earns. The expected point value for firing one round at a target is the product of the target point value and the sskp for that target. The target or targets for which the expected point value is the greatest will be the firer's preferred target. The algorithm is not integral; it will allocate fractional rounds to a target if that is what is optimal. For a mathematical treatment of the algorithm, see the technical paper CAA-TP-83-X, Expected Value Allocation Procedure, by Dr. DeRiggi.

(U) The actual attrition of forces is handled separately from the allocation of fire. Two heterogenous forces are divided into homogeneous classes firing at each of the opposing force homogeneous classes. Each class consists of a group of similar weapons with all members of the class having the same point value and sskp with respect to the opposing classes of weapons. The algorithm determines how many weapons within each group on one side are killed by each of the groups on the other side. The number attrited is function of the firing group sskp for the target type, the number of weapons in the firing group, the number of weapons in the target group, the probability of a single firer acquiring a particular target, and the number of rounds each firer has allocated to the target group. The mathematics of the algorithm can be found in the above referenced paper.

How Battles Were Analyzed

(U) A method was needed to fight controlled battles using the MTM+ attrition algorithm. To accomplish this task, a FORTRAN program was written whic allows the user to specify any number of the units in the MTM+ data list to engage enemy forces anywhere on the terrain board, for a specified length of time or to a given cutoff threshold , for a requested number of

epetitons. This driver program, named Arena, is linked with he MTM+ object code library to obtain an executable module. An nnotated listing of Arena has previously been prepared.

Units to Be Tested

(U) A number of representative US units were tested against typical Soviet motorized rifle division. The three units hich were run for this study were the 101st Air Assualt ivision, the 82nd Airborne Division, and a portion of the 24th echanized Infantry Division, as played by demonstration ersions of MTM+. The seven classes of weapons were: tanks; nfantry fighting vehicles; armored personnel carriers; nti-tank weapons; artillery and mortar pieces; air defense eapons; and, small arms. Each battle was set for twenty-four ours, and replicated ten times.

Results

(U) The results for the three cases are presented at Tables - 3. Each matrix is the seven-by-seven weapon class versus eapon class killer/victim scoreboard. The two values in each atrix entry are the US scores against Soviet (Top) and the oviet against US (Bottom) weapon classes. The units of these alues are kills/firer/day. Within the target value and sskp

TABLE I . US and Soviet Killer/Victim Scoreboard,
101ST AIR ASSAULT Division .

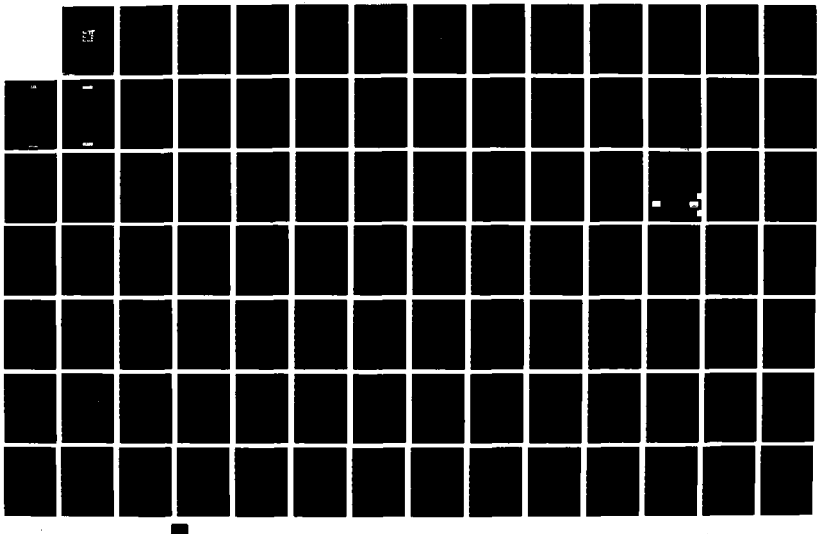
ttrited Weapon

TANK	IFV	APC	AT	ARTY	AD	Small Ar
ing						

Rates are in kills/firer/day.
Top value - US attriting Soviet
Bottom - Soviet attriting US

AD-A157 322 COMBAT MODELING EVALUATION AT THE UNITED STATES MILITARY ACADEMY(U) MILITARY ACADEMY WEST POINT NY V M BETTENCOURT JUN 85 2/3

UNCLASSIFIED F/G 9/2 NL



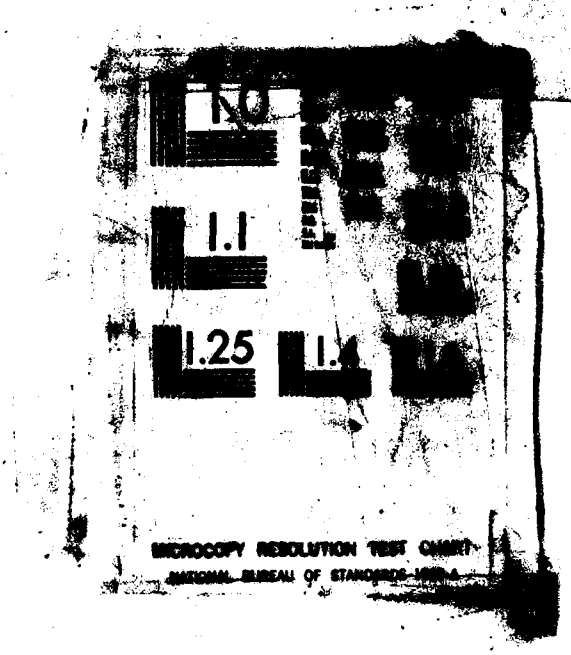

1.1
1.25
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE 2 . US and Soviet Killer/Victim Scoreboard,
82nd Airborne Division .

Attriting Weapon	Attrited Weapon: TANK	IFV	APC	AT	ARTY	AD	Small Arms
TANK							
IFV							
APC							
AT							
ARTY							
AD							
Small Arms							

Rates are in kills/firer/day.
Top value - US attriting Soviet
Bottom - Soviet attriting US

TABLE 3. US and Soviet Killer/Victim Scoreboard, 24TH INF (MECH) Division (-).

Attriting Weapon	Attrited Weapon: TANK	IFV	APC	AT	ARTY	AD	Small Arms
TANK							
IFV							
APC							
AT							
ARTY							
AD							
Small Arms							

Rates are in kills/firer/day.
Top value - US attriting Soviet
Bottom - Soviet attriting US

calculations are the assumptions that Soviet forces are attacking US forces in a prepared defense posture. The computer outputs listing the initial unit weapon strengths, and the mean, standard deviation, and maximum kill rates for the tests presented here are attached as an appendix.

Conclusions.

(U) The results from the MTM+ attrition algorithm are not realistic. More acceptable results could be achieved by tuning the target values and sskp's used in the game. However, I would recommend a different algorithm be employed, one that uses a more objective means for deriving the measures of target priority values, and also a stochastic allocation of an integral number of rounds fired, to make the model more nearly reflect the underlying allocation and attrition process.

APPENDIX

OUTPUT FROM THE ARENA PROGRAM

ATTRITION ALGORITHM TESTS

ANALYSIS OF BATTLE DATA

UNIT NUMBER	COLOR	EW LOC	NS LOC	THRESHOLD
703	BLUE	AC	3	0.0
80	RED	AC	5	0.0

NUMBER OF REPETITIONS 10
NUMBER OF HOURS PER BATTLE 4
INITIAL RANDOM NUMBER SEED 7364551
FINAL RANDOM NUMBER SEED 1906416393

FL2

RESULTS BLUE ATTRITING

WEAPON CLASS	INITIAL COUNT	1	2	3	4	5	6	7
		0	0	0	0	0	0	0
1	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
2	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
3	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
4	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
5	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
6	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
7	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

RESULTS RED ATTRITING

WEAPON CLASS	INITIAL COUNT	1	2	3	4	5	6	7
		0	0	0	0	0	0	0
1	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
2	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
3	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
4	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
5	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
6	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
7	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

ANALYSIS OF BATTLE DATA

UNIT NUMBER	COLOR	EW LOC	NS LOC	THRESHOLD
703	BLUE	AC	3	0.0
88	RED	AC	5	0.0

NUMBER OF REPETITIONS 10
NUMBER OF HOURS PER BATTLE 4
INITIAL RANDOM NUMBER SEED 7364551
FINAL RANDOM NUMBER SEED 1986414393

RESULTS BLUE ATTRITING

WEAPON CLASS	INITIAL COUNT	1	2	3	4	5	6	7
		0	0	0	0	0	0	0
1	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
2	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
3	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
4	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
5	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
6	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
7	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

RESULTS RED ATTRITING

WEAPON CLASS	INITIAL COUNT	1	2	3	4	5	6	7
		0	0	0	0	0	0	0
1	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
2	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
3	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
4	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
5	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
6	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
7	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

ANALYSIS OF BATTLE DATA

UNIT NUMBER	COLOR	EW LOC	NS LOC	THRESHOLD
703	BLUE	AC	3	0.0
80	RED	AC	5	0.0

NUMBER OF REPETITIONS 10
NUMBER OF HOURS PER BATTLE 4
INITIAL RANDOM NUMBER SEED 7364551
FINAL RANDOM NUMBER SEED 1906416393

RESULTS BLUE ATTRITING

WEAPON CLASS	INITIAL COUNT	1	2	3	4	5	6	7
		0	0	0	0	0	0	0
1	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
2	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
3	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
4	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
5	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
6	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
7	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

```
400     FORMAT(10(/),40X,'RESULTS',A4,' ATTRITING',
     _        /,'  WEAPON',/,
     _          '   CLASS',40X,2I10,/,
     _          10X,'    INITIAL',/,
     _          10X,'      COUNT',7I10,//)
410     FORMAT(2I10,4X,7E10.3)
420     FORMAT(24X,7E10.3)
430     FORMAT(24X,'-----------------------------------------------
     =----------------------------')
440     FORMAT('1')
        END
```

```
0288                BCLOCK=BCLOCK-IRAGE
0289                HOLDER=ISEED
0290                REWIND 44
0291      290       CONTINUE
0292                DO 300 ICOL=1,2
0293                 DO 300 I=1,7
0294                  DO 300 J=1,7
0295                   SUMX=RESULT(ICOL,I,J,1)
0296                   SQSUM=RESULT(ICOL,I,J,2)
0297                   RESULT(ICOL,I,J,1)=SUMX/IREPT
0298                   RESULT(ICOL,I,J,2)=(IREPT*SQSUM-SUMX**2)/
                                                  (IREPT*(IREPT-1))
0299                   IF (RESULT(ICOL,I,J,2).LT.0)RESULT(ICOL,I,J,2)=0
0300                   RESULT(ICOL,I,J,2)=RESULT(ICOL,I,J,2)**.5
0301      300       CONTINUE
0302                WRITE(85,320)
0303                WRITE(85,330)
0304                DO 310 INFIGHT=1,JNUM
0305                WRITE(85,340)NUNIT(IFILE(INFIGHT)),UNITCL(IFILE(INFIGHT))
0306           -                IEW(INFIGHT),INS(INFIGHT),TRH(INFIGHT)
0307      310       CONTINUE
0308                WRITE(85,350)IREPT,IRAGE,INSEED,ISEED
0309                WRITE(85,360)
0310                DO 380 ISDE=1,2
0311                 NOSP=3-ISDE
0312                 ATTACK='RED '
0313                 IF(ISDE.EQ.1)ATTACK='BLUE'
0314                 WRITE(85,400)ATTACK,(NW,NW=1,7),(NSTART(NOSP,LW),LW=1,7)
0315                 DO 370 NW=1,7
0316                  WRITE(85,410)NW,NSTART(ISDE,NW),(RESULT(ISDE,NW,NME,1),
0317           -                    NME=1,7)
0318                  WRITE(85,420)((RESULT(ISDE,NW,NME,IDT),NME=1,7),IDT=2,3)
0319                  WRITE(85,430)
0320      370        CONTINUE
0321                 WRITE(85,440)
0322      380       CONTINUE
0323      390      CONTINUE
0324               CALL GRAFX(8)
0325      10       FORMAT(I5)
0326      40       FORMAT(I4,/,I4,/,I4)
0327      50       FORMAT(I4,/,F5.2,/,A2,/,I2)
0328      60       FORMAT(I12)
0329      200      FORMAT(A5)
0330      210      FORMAT(12(/))
0331      240      FORMAT(14(/))
0332      260      FORMAT(20X,7E10.1)
0333      320      FORMAT(10(/),40X,'ANALYSIS OF BATTLE DATA')
0334      330      FORMAT(//,2X,'UNIT NUMBER',7X,'COLOR',9X,'EW LOC',9X,
                                                      'NS LOC',
0335           -                  8X,'THRESHOLD')
0336      340      FORMAT(4X,I4,12X,A4,11X,A2,13X,I4,12X,F5.1)
0337      350      FORMAT(/,X,'NUMBER OF REPETITIONS',I4,/,X,'NUMBER OF HOURS
0338           -    PER BATTLE',I4,/,X,'INITIAL RANDOM NUMBER SEED ',I12,/,X,
0339           -   'FINAL RANDOM NUMBER SEED ',I12)
0340      360      FORMAT('1')
```

```
0234                ISEED=HOLDER
0235     100        DO 130 ILOC=1,JNUM
0236                 POINTS(IFILE(ILOC))=IPOINT(ILOC)
0237                 PERCNT(IFILE(ILOC))=PRCNT(ILOC)
0238                 DO 110 ISUP=1,12
0239                  SUPPLY(IFILE(ILOC),ISUP)=IFORCE(ILOC,ISUP)
0240     110         CONTINUE
0241                 DO 120 IWEP=1,7
0242                  NUMBERWEAPONS(IFILE(ILOC),IWEP)=IWEAPON(ILOC,IWEP)
0243     120         CONTINUE
0244                 EW(IFILE(ILOC))=IEW(ILOC)
0245                 NS(IFILE(ILOC))=INS(ILOC)
0246                 THRES(IFILE(ILOC))=TRH(ILOC)
0247                 EWNEXT(IFILE(ILOC))=IEW(ILOC)
0248                 NSNEXT(IFILE(ILOC))=INS(ILOC)
0249                 EWFIRE(IFILE(ILOC))=IEW(ILOC)
0250                 NSFIRE(IFILE(ILOC))=INS(ILOC)
0251     130        CONTINUE
0252                IF ((IRON.EQ.1).AND.(NOB.EQ.1))CALL GRAFX(0)
0253                IF((IRON.EQ.1).AND.(NOB.NE.1))CALL GRAFX(1)
0254     140        DO 160 M=1,IRAGE/2
0255                 BATTIM=BCLOCK
0256                 CALL COMBAT(IFRESH)
0257                 IF( NBATL.NE.0)GOTO 150
0258                 IRAGE=M*2
0259                 GOTO 170
0260     150         BCLOCK=BCLOCK+2
0261     160        CONTINUE
0262     170        REWIND 44
0263                DO 265 IOVER=1,IRAGE/2-1
0264                 DO 190 LINE=1,2
0265     180          READ(44,200)IRCAT
0266                  IF(IRCAT.NE.'-----')GOTO 180
0267     190          CONTINUE
0268                 READ(44,210)
0269                 DO 250 ICOL=1,2
0270                  DO 230 I=1,7
0271                   READ(44,260)(DEAD(ICOL,I,J),J=1,7)
0272                   DO 220 J=1,7
0273                    ONCE(ICOL,I,J)=ONCE(ICOL,I,J)+DEAD(ICOL,I,J)
0274     220           CONTINUE
0275     230          CONTINUE
0276                  IF (ICOL.EQ.1)READ(44,240)
0277     250          CONTINUE
0278     265        CONTINUE
0279                DO 280 ICOL=1,2
0280                 DO 280 I=1,7
0281                  DO 280 J=1,7
0282                   RESULT(ICOL,I,J,1)=RESULT(ICOL,I,J,1)+ONCE(ICOL,I,J)
0283                   RESULT(ICOL,I,J,2)=RESULT(ICOL,I,J,2)
                                          +ONCE(ICOL,I,J)**2
0284                   IF(RESULT(ICOL,I,J,3).GT.ONCE(ICOL,I,J))GOTO 270
0285                   RESULT(ICOL,I,J,3)=ONCE(ICOL,I,J)
0286     270           ONCE(ICOL,I,J)=0
0287     280        CONTINUE
```

```
0001            INCLUDE 'PROC.'
0181            INTEGER HOLDER
0182            CHARACTER IEW*2,IRCAT*5
0183            DIMENSION IEW(40),ID(40),TRH(40),INS(40),IFILE(40)
0184            DIMENSION IPOINT(40),PRCNT(40),IWEAPON(40,7),IFORCE(40,1
0185            DIMENSION RESULT(2,7,7,3),ONCE(2,7,7),NSTART(2,7),
                          DEAD(2,7,7)
0186            CALL SYS$CREMBX(,ICHAN,,,,,'GRAPHICS')
0187            OPEN(UNIT=66,NAME='GRAPHICS',CARRIAGECONTROL='LIST',
0188           -             STATUS='UNKNOWN')
0189            WRITE(66,10) 1
0190            TRACE=.FALSE.
0191            PRINT*,'IN VITRO ANALYSIS OF MTM+ COMBAT ATTRITION'
0192            PRINT*,' '
0193            PRINT*,'HOW MANY BATTLES DO WANT TO RUN?'
0194            READ*,NBAT
0195            DO 390 NOB=1,NBAT
0196             CALL INDATA
0197             CLOSE(UNIT=14)
0198             DO 20 ICOL=1,2
0199              DO 20 I=1,7
0200               DO 20 J=1,7
0201                DO 20 K=1,3
0202                 ONCE(ICOL,I,J)=0
0203                 DEAD(ICOL,I,J)=0
0204                 RESULT(ICOL,I,J,K)=0
0205                NSTART(ICOL,I)=0
0206     20        CONTINUE
0207             READ(86,40)JNUM,IREPT,IRAGE
0208             DO 30 J=1,JNUM
0209              READ(86,50)ID(J),TRH(J),IEW(J),INS(J)
0210     30       CONTINUE
0211             IF(NOB.EQ.1)READ(86,60)ISEED
0212             IF(NOB.NE.1)ISEED=HOLDER
0213             INSEED=ISEED
0214             IRAGE=INT(IRAGE/2)*2
0215             DO 90 LOC=1,NUMBERUNITS
0216              DO 90 ILOC=1,JNUM
0217               IF(ID(ILOC).NE.NUNIT(LOC))GOTO 90
0218               IFILE(ILOC)=LOC
0219               IPOINT(ILOC)=POINTS(LOC)
0220               PRCNT(ILOC)=PERCNT(LOC)
0221               DO 70 IWEP=1,7
0222                IWEAPON(ILOC,IWEP)=NUMBERWEAPONS(LOC,IWEP)
0223                ICOL=1
0224                IF(UNITCL(LOC).EQ.'RED ')ICOL=2
0225                NSTART(ICOL,IWEP)=NSTART(ICOL,IWEP)+IWEAPON(ILOC,IWEP)
0226     70         CONTINUE
0227               DO 80 ISUP=1,12
0228                IFORCE(ILOC,ISUP)=SUPPLY(LOC,ISUP)
0229     80         CONTINUE
0230     90       CONTINUE
0231             DO 290 IRON=1,IREPT
0232              PRINT*,'STARTING REP',IRON,'       OF BATTLE',NOB
0233              IF(IRON.EQ.1)GOTO 100
```

LISTING OF ARENA

OUTPUT FORMAT

WHEN FILE 85 IS PRINTED EACH BATTLE IS
REPORTED ON THREE PAGES OF OUTPUT

THE FIRST PAGE CONSISTS OF A SYNOPSIS OF
PERTINENT BATTLE DATA
IT GIVES THE UNITS INVOLVED IN THE COMBAT,
THEIR COLORS, LOCATIONS AND THRESHHOLDS

THE SECOND AND THIRD PAGES ARE THE ATTRITION
RESULTS FOR EACH WEAPON ON WEAPON PAIR,.
FIRST FOR BLUE WEAPONS ATTRITNG RED WEAPONS
AND THEN FOR RED WEAPONS ATTRITING BLUE
WEAPONS

EACH WEAPON ON WEAPON PAIR HAS A BLOCK OF
THREE VALUES ASSOCIATED WITH IT

THE VALUES ARE ;

MEAN AMOUNT ATTRITED
STANDARD DEVIATION
MAXIMUM ATTRITED

****

HOW TO RUN ARENA

```
FIRST; EDIT FILE FOR086.DAT

      INTO THIS FILE, ENTER DATA FOR BATTLES IN THIS ORDER;
        NUMBER OF UNITS IN BATTLE
        NUMBER OF REPITITIONS
        NUMBER OF HOURS THE BATTLE WILL BE FOUGHT
      THEN FOR EACH UNIT IN THE BATTLE ENTER;
        UNIT IDENTIFICATION NUMBER
        THRESHOLD
        EAST WEST LOCATION
        NORTH SOUTH LOCATION
      ONLY IF THIS IS THE FIRST BATTLE ENTER;
        RANDOM NUMBER SEED
      REPEAT FOR EACH DIFFERENT BATTLE TO BE RUN


EXIT FROM FILE086.DAT AND

ASSIGN INPUT.DAT FOR014
ASSIGN GFXIN.DAT FOR067

ON ONE TERMINAL RUN ARENA
ON A SECOND TERMINAL RUN DRIVER

WHEN PROMPTED, ENTER THE NUMBER OF BATTLES
                 TO BE RUN

AFTER PROGRAM IS COMPLETE
PRINT FILE FOR085.DAT TO OBTAIN RESULTS
```

THRES	ARRAY OF UNIT THRESHOLD VALUES IN FILE INPUT.DAT
EWNEXT	ARRAY OF EAST WEST DESTINATIONS IN FILE INPUT.DAT
NSNEXT	ARRAY OF NORTH SOUTH DESTINATIONS IN FILE INPUT.DAT
EWFIRE	ARRAY OF EAST WEST TARGET LOCATIONS IN FILE INPUT.DAT
NSFIRE	ARRAY OF NORTH SOUTH TARGET LOCATIONS IN FILE INPUT.DAT
M	CURRENT TWO HOUR BLOCK OF COMBAT
BATTIM	TIME OF TWO HOUR BLOCK OF COMBAT
BCLOCK	GAME TIME
NBATL	NUMBER OF ENGAGEMENTS DURING CURRENT TWO HOUR BLOCK OF COMBAT
IOVER	CURRENT TWO HOUR BLOCK OF COMBAT
LINE	FIRST OR SECOND DASHED LINE IN FILE44
IRCAT	STRING TO FIND DASHED LINES IN FILE44
SUMX	SUM OF AMMOUNTS ATTRITED IN CURRENT BATTLE
SQSUM	SUM OF SQUARES OF AMOUNTS ATTRITED IN CURRENT BATTLE
INFIGHT	NUMBER OF UNIT AMONG UNITS IN CURRENT BATTLE
ISDE	SIDE NUMBER
ATTACK	COLOR OF SIDE FIRING
NW	WEAPON TYPE
LW	WEAPON TYPE
NME	EAPON TYPE
IDT	STATISTIC TO BE CALCULATED

LISTING AND DEFINITION OF VARIABLES IN ORDER OF APPEARANCE

NBAT	NUMBER OF DIFFERENT BATTLES TO BE RUN
NOB	CURRENT BATTLE BEING ANALYZED
ICOL	COLOR OF SIDE 1=BLUE, 2=RED
I	FRIENDLY WEAPON TYPE
J	ENEMY WEAPON TYPE
K	STATISTIC TO BE CALCULATED
ONCE	ARRAY TO STORE ATTRITION DATA FOR CURRENT REPT.
DEAD	ARRAY TO STORE ATTRITION DATA FOR TWO HOUR BLOCK OF COMBAT
RESULT	ARRAY TO STORE ATTRITION DATA FOR CURRENT BATTLE
NSTART	ARRAY TO STORE INITIAL WEAPON INVENTORIES
JNUM	NUMBER OF UNITS IN CURRENT BATTLE
IREPT	NUMBER OF REPITITIONS TO RUN OF CURRENT BATTLE
IRAGE	NUMBER OF HOURS CURRENT BATTLE IS FOUGHT
ID	ARRAY TO STORE UNIT ID NUMBER
TRH	ARRAY TO STORE UNIT THRESHOLD
IEW	ARRAY TO STORE UNIT EAST WEST LOCATION
INS	ARRAY TO STORE UNIT NORTH SOUTH LOCATION
ISEED	RANDOM NUMBER SEED
HOLDER	FINAL RANDOM NUMBER SEED FROM PREVIOUS REPITIION
INSEED	RANDOM NUBER SEED AT START OF REPTITIONS OF CURRENT BATTLE
LOC	LOCATION OF UNIT IN FILE INPUT.DAT
NUMBERUNITS	NUMBER OF UNITS IN FILE INPUT.DAT
ILOC	LOCATION OF UNIT AMONG UNITS IN CURRENT BATTLE
NUNIT	ARRAY OF UNIT IDENTIFICATION NUMBERS IN FILE INPUT.DAT
IFILE	ARRAY TO STORE UNIT IDENTIFICATION NUMBERS
IPOINT	ARRAY TO STORE POINT VALUE OF UNITS
POINT	ARRAY OF UNIT POINT VALUES IN FILE INPUT.DAT
PRCNT	ARRAY TO STORE PERCENTAGE OF UNIT STRENGTHS REMAINING
PERCNT	ARRAY OF PERCENTAGE OF UNIT STRENGTHS REMAINING IN FILE INPUT.DAT
IWEP	WEAPON TYPE
IWEAPON	ARRAY TO STORE NUMBER OF WEAPONS OF EACH TYPE BY UNIT
NUMBERWEAPONS	ARRAY OF NUMBER OF WEAPONS OF EACH TYPE BY UNIT IN FILE INPUT.DAT
UNITCL	ARRAY OF UNIT COLORS IN FILE INPUT.DAT
ISUP	SUPPLY CATEGORY
IFORCE	ARRAY TO STORE SUPPLIES ON HAND IN UNITS
SUPPLY	ARRAY OF SUPPLIES ON HAND IN UNITS IN FILE INPUT.DAT
IRON	CURRENT REPITITION
EW	ARRAY OF EAST WEST LOCATIONS IN FILE INPUT.DAT
NS	ARRAY OF NORTH SOUTH LOCATIONS IN FILE INPUT.DAT

```
300-306                  WRITE PERTINENT BATLE IDENTIFICATION DATA
                           INTO FILE 85
[308-320]                FOR BOTH SIDES

[313-318]                   FOR ALL FRIENDLY WEAPON TYPES

[314,315]                      FOR ALL ENEMY WEAPON TYPES

314                               WRITE MEAN AMOUNT ATTRITED INTO FILE 85

[316]                          FOR ENEMY WEAPON TYPES

316                               WRITE STANDARD DEVIATION AND MAX OF
                                   AMOUNT ATTRITED INTO FILE 85

324-348          FORMAT STATEMENTS
349              END OF PROGRAM
```

```
                        BATTLE UPDATE MAP
[254-261]               FOR EACH TWO HOUR BLOCK

256                        CALL THE MTM+ COMBAT ROUTINE
257-259                    IF THERE WAS NO COMBAT STORE LENGTH
                            OF TIME BATTLE WAS ACTUALLY FOUGHT
                            AND SKIP TO END OF TIME ALLOTTED
                            FOR BATTLE

[263-278]               FOR EACH TWO HOUR BLOCK OF COMBAT

264-268                    LOCATE KILLER, VICTOM SCOREBOARD IN
                            FILE 44
[269-277]                  FOR BOTH SIDES

[270-275]                     FOR ALL FRIENDLY WEAPON TYPES

271                              READ IN NUMBER OF ENEMY WEAPONS
                                  ATTRITED, BY TYPE
273                              ADD AMOUNT ATTRITED TO PREVIOUS
                                  AMOUNT ATTRITED DURING CURRENT
                                  REPITITION

[279-287]               FOR BOTH SIDES

[280-287]                  FOR ALL FREINDLY WEAPON TYPES

[281-287]                     FOR ALL ENEMY WEAPON TYPES

282                              ADD AMOUNT ATTRITED IN REPITITION
                                  TO PREVIOUS SUM OF AMOUNTS ATTRITED
                                  DURING CURRENT BATTLE
283                              ADD SQUARE OF AMOUNT ATTRITED IN
                                  REPITITION TO PREVIOUS SUM OF
                                  SQUARES OF AMOUNTS ATTRITED DURING
                                  CURRENT BATTLE
284-285                          IF AMOUNT ATTRITED DURING CURRENT
                                  REPITITION IS GREATER THAN ALL
                                  PREVIOUS AMOUNTS ATTRITED STORE
                                  AMOUNT ATTRITED
286                              RESET AMOUNT ATTRITED DURING
                                  REPITITION TO ZERO

288                        SET BATTLE CLOCK BACK TO TIME AT START OF
                            REPITITION
289                     STORE FINAL RANDOM NUMBER SEED FOR REPITITION
[292-299]               FOR BOTH SIDES

[293-299]                  FOR ALL FRIENDLY WEAPON TYPES

[294-299]                     FOR ALL ENEMY WEAPON TYPES

294-298                          CALCULATE MEAN AND STANDARD DEVIATION
                                  OF AMOUNT ATTRITED FOR TOTAL NUMBER
                                  OF REPITITIONS
```

THE PURPOSE OF ARENA IS TO ANALYZE COMBAT ATTRITION IN THE MCCLINTIC THEATER MODEL-PLUS OUTSIDE OF THE GAME.

THIS GOAL IS ACCOMLISHED BY

LINE NUMBER	CODE FUNCTION
1	APPEND ARENA TO PROC.
183-185	DIMENSION ARRAYS
194	READ IN NUMBER OF BATTLES TO BE FOUGHT
[195-321]	FOR EACH BATTLE
196	READ IN UNIT DATA FROM FILE INPUT.DAT
198-206	INITIALIZE ARRAYS WITH ZERO VALUE
207	READ IN NUMBER OF UNITS IN THE BATTLE, THE NUMBER OF TIMES THE BATTLE WILL BE FOUGHT AND THE NUMBER OF HOURS THE BATTLE WILL BE FOUGHT
[208-210]	FOR EACH UNIT IN THE BATTLE
209	READ UNIT NUMBER,THRESHOLD AND LOCATION
211	IF IT IS THE FIRST BATTLE, READ IN A RANDOM NUMBER SEED
212	IF IT IS NOT THE FIRST BATTLE, SET THE RANDOM NUMBER SEED EQUAL TO ITS FINAL VALUE FOR THE LAST BATTLE
[215-230]	FOR EACH UNIT IN THE BATTLE
216-218	LOCATE UNIT IN INPUT.DAT
219-229	STORE UNIT DATA
[231-291]	FOR EACH REPITITION
232	PRINT OUT STATUS REPORT TO TERMINAL
233	IF IT IS NOT THE FIRST REPITITION SET THE RANDOM NUMBER SEED EQUAL TO ITS VALUE AT THE END OF THE LAST REPITITION
[235-251]	FOR EACH UNIT
236-250	SET UNIT DAT BACK TO VALUES PRIOR TO LAST REPITITION
252	IF ON FIRST REPITITION OF FIRST BATTLE SET UP MAP
253	IF ON FIRST REPITITION OF ALL BUT FIRST

USER DOCUMENTATION FOR
ARENA
****
A FORTRAN PROGRAM

WRITTEN BY CADET THOMAS A DUFRESNE
MAY-JUN 1984
DURING VOLUNTEER SUMMER TRAINING PROGRAM
AT THE US ARMY CONCEPTS ANALYSIS AGENCY
BETHESDA, MARYLAND

RESULTS RED ATTRITING

WEAPON CLASS	INITIAL COUNT	1	2	3	4	5	6	7
1	0	0	0	0	0	0	0	0
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
2	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
3	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
4	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
5	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
6	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
7	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

TEST OF MODEL INTERFACE PROGRAM IN THE JOINT THEATER LEVEL SIMULATION

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Cadet USMA 1985

(In cooperation with Mr. Dave Brownell ITD)

The purpose of this test is to test the directives in the Model Interface Program (MIP) of the Joint Theater Level Simulation (JTLS). The format for MIP Test Plan was set up to test valid, invalid and null inputs. For each of the inputs there is an expected output. For example, the MIP should accept a valid input and reject an invalid input. The test entries which were used included a valid, invalid and null input. As for output, there were two types of expected results which are acceptance of the input and rejection of the input.

Each directive in the MIP is made up of several different fields. A field is considered an entry that is needed for a directive to be processed. The field can be a mandatory, optional, regulating, or conditional field. For example if it is a mandatory field an entry must be made.

The format of the test was derived and every directive was put in that format. The actual testing consists of entering all the different types of valid, invalid and null inputs in each field of all the forty-seven directives. The testing was not completed, but the format along with the valid and invalid entry list was finished.

Definitions used in the MlP test:

1. V Entry - A valid entry. For integer and real data types, the entry lies within the range of acceptable values and for the text data type, the entry is an appropriate entry. When applicable, the entry matches a corresponding data base entry.

   a. Vmax - For integer and real data types, the maximum valid entry.

   b. Vmin - For integer and real data types, the minimum valid entry.

   c. V# - A valid entry which is defined by a note at the bottom of the test.

2. I Entry - An Invalid entry. For integer and real data types, the entry may lie outside the range of acceptable values and for the text data type, the entry may not be an appropriate entry. When applicable, the entry may not match a corresponding data base entry.

3. N Entry - A null entry. No entry is provided.

4. M field - A mandatory field. An entry must be provided in mandatory fields for the directive to be processed. Mandatory entries may be defaults provided by the simulation system.

5. O field - An optional field. Entries may or may not be provided in an optional field.

   R field - A regulating field. The entry in a regulating field determines whether mandatory or null entries must be provided in the conditional field(s) it regulates.

7. C field - A conditional field. When specific entries are provided in a regulating field, entries are mandatory in the conditional field(s) it regulates. At other times, the conditional field(s) must have null entries.

8. Expected Result 1 - No error conditions.

9. Expected Result 2 - Error condition - Invalid entry. Entry not accepted.

The test of the MIP was conducted as follows: At first a format was developed which included all the fields in bookkeeping manner. Underneath each field the .id, invalid and null variables were entered. The last entry after all the fields were entered would be the expected result. The expected result was either an acceptance or rejection of the values entered in the fields.

Field 1	field 2	Expected Result
V	Vmax	1
V	Vmin	1
I		2
V	I	2
N		2
V	N	2
1-M	2-M	

In this first example both of the fields were mandatory only having the responses of valid, invalid and none. The second field has a maximum and a minimum value associated with it ; therefore, the test should consider both of these values. A field which has maximums and minimums is usually a field which has a number or time associated with it. In the test the type of field was always entered at the bottom of the test form similar to this example.

Another example is when there is an optional and a mandatory field.

Field 1	Field 2	Expected Result
V	V	1
V	N	1
I		2
V	I	2
N		2
1-M	2-O	

In this case two entries would be accepted because of the optional field which should accept the null entries.

Another example is when a regulating and a conditional field are present.

field 1	field 2	field 3	field 4	Expected Result
V	V#1	V		1
V	V#2		V	1
I				2
V	I			2
V	V#1	I		2
V	V#2		I	2
N				2
V	N			2
V	V#1	N		2
V	V#2		N	2
1-M	2-R (3-4)	3-C (2)	4-C (2)	

#1 only field 3 entry is needed
#2 only field 4 entry is needed

In this case the 2d field regulates the 3d and 4th field. The 3d and 4th field are dependent on what is entered in the 2d field. If V 1 is entered in the regulating field then only one other entry needs to be made in the 3d conditional field.

Throughout the test, mandatory, optional, regulating and conditional fields were used. On the average, there were about eight different fields for each directive.

Each directive was formatted into the different types of fields. Then the combinations of valid, invalid and null entries were added. After this was completed, a table was made so the valid and invalid entries used in each field could be recorded. This was formatted as follows:

FIELD	V	Vmax	Vmin	I
1				
2				
3				

Each directive was formatted in this way. Combining this format a test for first directive in the MIP Tactical Threshold would look like the following

JTLS TEST PLAN: MIP Input/Output Test Procedure

TACTICAL THRESHOLD Command

Date Prepared: _____ Prepared by: _____

Date Tested: _____ Tested by: _____

Reference	Group	Unit	Purpose	Threshold to Change	Threshold	Expected Result
V	V	V	V#1	V#3	Vmax	1
V	V	V	V#1	V#3	Vmin	1
V	V	V	V#1	V#4	Vmax	1
V	V	V	V#1	V#4	Vmin	1
V	V	V	V#1	V#5	Vmax	1
V	V	V	V#1	V#5	Vmin	1
V	V	V	V#1	V#6	Vmax	1
V	V	V	V#1	V#6	Vmin	1
V	V	V	V#1	V#7	Vmax	1
V	V	V	V#1	V#7	Vmin	1
V	V	V	V#1	V#8	Vmax	1
V	V	V	V#1	V#8	Vmin	1
V	V	V	V#2			1
V	N					1
I						2
V	I					2
V	V	I				2
V	V	V	I			2
V	V	V	V	I		2
V	V	V	V	V	I	2
1-M	2-O	3-M	4-R (5-6)	5-C (4)	6-C (4)	

(CONTINUED)

ference	Group	Unit	Purpose	Threshold to Change	Threshold	Expected Result
N						2
V	V	N				2
V	V	V	N			2
V	V	V	V	N		2
V	V	V	V	V	N	2
-M	2-O	3-M	4-R (5-6)	5-C (4)	6-C (4)	

CHANGE Threshold
REPORT Threshold
RESHOLDS THAT CAN BE CHANGED
Attack: Defend
Defend: Delay
Delay: Withdraw
Withdraw: Ineffective
Ineffective: Wiped Out

JTLS TEST PLAN: MIP Input/Output Test Procedure

TACTICAL THRESHOLD Command

LD	V	Vmax	Vmin	I
	TEST	-	—	123456789
	1234ABA	-	—	123456789
	101/3	-	—	102A
	CHANGE NEXT	--	—	CHARGE
	1,2,3,4,5, or 6	-	—	0 or 8
	.75	1.0	.01	.005

After the format was developed, the valid and invalid entries were found by
g through each field in every directive. This was the end point of our
ect. Our next step would have been actually conducting the test. The
ing includes putting the valid and invalid entries in every case that was
loped in the format portion of this test.

In conclusion this test was developed to test the MIP and its ability to
pt and reject valid, invalid and null entries. This test provides an
nized format to help in the testing of the MIP.

TACTICAL THRESHOLD

Purpose: Either changes one of the tactical thresholds at which a unit will change posture or reports to you concerning all thresholds.

Input Forms: TACTICAL THRESHOLD or TT

Attributes:

1. REFERENCE: Player-selected identifier
2. GROUP: Optional. Player-selected identifier for a group of directives to be sent to the CEP at one time.
3. UNIT: The name of any unit on your side.
4. PURPOSE: Enter either "REPORT" or "CHANGE." If REPORT is entered, directive is complete.
5. THRESHOLD TO CHANGE: Enter the number of the desired choice. The appropriate threshold item (or all of them) will be used as a prompt for the new value.

THE GROUND ATTRITION PROCESS OF THE JOINT THEATER-LEVEL SIMULATION MODEL

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ie routine then totals up the number of casualties
nflicted on each system. The ATTRITION.CALCULATION routine
ill divide these casualties evenly among all units in that
ex. These will be subtracted from the unit strength after
ll units have undergone ground attrition at the end of within the time step by the
ROUND.DECREMENT.FORCES routine called by the ASSESS.COMBAT
vent. The supplies used will be estimated by the
ROUND.ATTRIT.SUPPLIES routine, also called by the
SSESS COMBAT event, using the number of casualties received
y the unit and the unit's posture during attrition. The
outine will then subtract this estimate from the units
upplies. The ATTRITION.CALCULATION routine will then
peat the process for the next hex. When the attrition
used by all the surrounding hexes has been computed, the
outine will return to the ASSESS.COMBAT event. This event
ill then repeat the process for the next unit in combat.

zero, attrition will not occur. Then the ATTRITION.CALCULATION routine will then check the next unit in the nex. Otherwise the routine will then finish the assignment of the number of combat systems facing in the direction of the enemy unit that is currently causing attrition. The routine then computes the combat power of the enemy (attritor) unit that is facing the friendly (attritee) unit. It also checks to make sure that the unit is within a weapons system's range before allowing it to cause casualties to an enemy unit.

The system then checks the ammunition and supply status of the unit causing attrition. Units that are out of ammunition cannot inflict casualties on another unit. It also checks any reinforcing units (DS, GSR and GS Artillery) to see that they are not in combat with another unit, are in range and have ammunition. It also checks whether the unit has fuel. The routine then penalizes each weapons system that is fuel dependent (such as tanks or SP howitzers) for attritor units and their reinforcing units that are out of fuel. The routine then uses the index number from the WHO.DOES.WHAT.TO.WHOM routine to select the corresponding table of Lanchester attrition coefficients (see Figure 2: FWL. Coefficients). For each attritor weapons system, the ATTRITION.CALCULATION routine selects the appropriate coefficient (Figure 2) and substitutes it into either the Lanchester Area Fire Equation for indirect fire systems or the Lanchester Aimed Fire Equation for direct fire systems.

Section 3. JTLS ATTRITION SUBROUTINE SUMMARY

3.1 JTLS Ground Attrition Process.

The ground combat attrition in the JTLS CEP occurs at a set interval governed by the ASSESS.COMBAT event. The ASSESS.COMBAT event checks each unit to see if it is in combat. If it is in combat, the event calls the ATTRITION.CALCULATION routine to simulate the attrition on the unit. The routine checks the surrounding hexes to see if the unit is still in combat. If it is not, the routine exits back to ASSESS.COMBAT. If the unit is still in combat (enemy units are in adjacent hexes), the routine determines the unit's color and the enemy unit's color.

The attrition routine's next major task is to allocate the unit's combat power among the six hexsides according to the input data base. This is done for each of the unit's weapon systems. Then for each adjacent hex the routine calculates the attrition caused by the units in that hex. The routine first checks to see if the hex is occupied. If it is not occupied, the routine goes to the next hex. Otherwise, it will check to see if the friendly unit is within range of the enemy unit's longest range weapon. If the unit is out of range, combat cannot occur. In that case it will check the next unit in the hex. If the unit is in range, the routine will check the postures (attack, defend, admin etc) of both units against the COMBAT.INDEX (Figure 3). using the WHO.DOES.WHAT.TO.WHOM routine. If the index is

Endnotes for Section 2.

[1] The reader who desires more information should read LANCHESTER-TYPE MODELS OF WARFARE and A TUTORIAL ON THE DETERMINATION OF SINGLE-WEAPON-SYSTEM-TYPE KILL RATES FOR USE IN LANCHESTER-TYPE COMBAT MODELS by Professor James G. Taylor of the Naval Postgraduate School.

[2] BASED ON AN ANALYSIS OF THE JTLS ~~FEATURES~~ ANALYST GUIDE AND THE SIMSCRIPT CODING CONTAINED IN JTLS VERSION 1.0.

[3] ~~This is done~~ the maximum number of casualties a unit can incur is bounded to the number of each weapons systems the unit engages the enemy with. Technically JTLS the number of casualties per weapons system in JTLS ~~cannot exceed the number of a weapons system~~ can not exceed the)

→ minimum (number of a weapons system or number of casualties incurred during attrition).

Mathematically this is shown in Section 4.

The system used in the JTLS model is basically the same as this one just described. In addition to the steps discussed above, it checks to see if a weapons system is in range and has ammunition before it can cause attrition. It also weakens the power of a unit that is fuel dependent and is out of fuel. The JTLS system also uses different sets of coeffients for different unit postures, time of day and weather. The attriton process for the JTLS model is described in detail in the next section and the exact Lanchester attrition equations are identifed and described in section 4.

how? Q?P?

Where.

ΔV_i = The number of casualties to the victim(attritee) from ??
combat system type i.

K_J = The number of killer(attritor) weapon type J.

M = Total number of types of enemy weapons.

D_J = Direct fire switch; D=1 if weapon type J is direct fire, D=0 otherwise.

I_J = Area fire switch; I=1 if weapon type J is indirect fire, I=0 otherwise.

Q_{ij} = Rate at which weapon type J kills system i, using aimed fire.

P_{ij} = Rate at which weapon type J kills system i, using area fire.

The equation works by calculating the number of casualties inflicted on a given system by each of the enemy systems. The number of Soviet tanks destroyed, for example, would be the sum of the number of tanks killed by the M-1s, the infantrymen, the mortars and the TOWs. The casualties to the BMPs and Soviet infantrymen would be calculated in the same manner. This requires i*j number of Lanchester attrition coefficients for each side where i and j denote the number of different combat systems each side owns.

M-1 tanks, 84 infantry soldiers, 3 81mm mortars and 4 TOW teams. The Soviets have 4 T-62 tanks, 13 BMP MICVs and 96 motorized rifle troops. The mortar is an indirect fire weapon and requires the use of the area fire equation to calculate the attrition that it inflicts on the Soviets. The other weapon systems are direct fire and use the aimed fire equation. The casualties that result from an engagement between these two forces can be modelled using a mixed heterogeneous Lanchester equation. The form of the equation could be:

$$/\!\backslash V_i = \sum_{j=1}^{M} D_{ij} * G_j * K_j + \sum_{j=1}^{M} I_{ij} * P_j * K_j * V_i$$

are in the impact area the more casualties that result. With armored vehicles the more armored vehicles in the target area, the greater the chance that there will be a direct hit on one of them. In our example situation, we could assume that it takes 30 seconds for the Forward observer to relay the target location, 30 seconds for the fire direction center to compute the data and relay it to the guns, 15 seconds to load the gun and 15 seconds for the round to impact. Also assume that it takes one hit to kill a target and assume that because of the Soviets disposition and the terrain, it takes 6 rounds to hit any troops. This results in an expected kill time of 9 minutes. This gives a value of b=1 kill/9 minutes=.11 kills/minute. In the first minute of combat the number of casualties would be given by the equation dx/dt=-.11(6)(150)=99. The second minute's casualties are represented by dx/dt=-.11(6)(51)=34. The third minutes casualties are represented by dx/dt=-.11(6)(17)=11. This process continues until the Americans cease fire or the Soviets are all killed. Notice the casualty rate (casualties/troops) decreases as the Soviets lose more troops.

2.5 Mixed Heterogeneous Attrition.

A mixed heterogeneous attrition process involves situations where both direct and indirect fire are involved and each side has one or more different types of weapons, as used in JTLS. Consider a case where the Americans have 4

assumption of a constant strength over the assessment time interval is made in order to keep the attrition process simple. This allows the attrition process to be solved analytically. The approximation is good for small periods of assessments.

JTLS Time step?

2.4 Area/Indirect Fire.

To illustrate the area fire process, let us assume a situation where we have an American 155mm. howitzer battery (6 guns) against a Soviet airborne company of 150 men. The Americans are not in the line of sight of the Soviets who can only fire in a direct fire mode. Thus, they are not subject to attrition from the Soviet firepower. The Americans are using indirect fire so the Lanchester area fire equation applies. The Lanchester area fire equation is based on the assumption that the number of casualties caused by indirect fire is a function of not only the number of enemy weapons and their effectiveness, but also the number of targets in the area. Mathematically this is:

$$dx/dt=-byx,$$

where the coefficient b here represents the effectiveness of the indirect fire and the vulnerability of the targets to the enemy fire. This makes sense because indirect fire kills everything within its impact area (lethal?) except armored vehicles which require a direct hit. The more targets that

To prevent this from occuring, the number of casualties is limited to maximum number of teams. ~~so the anti-tank platoon would be wiped out while the tank unit would lose 24 tanks.~~ That is, 12 four teams [37] not necessarily so.

Using the above equations the number of enemy weapons killed depends only on the expected kill time and the number of firing units. The number of targets did not affect the casualties except the casualties could not exceed the total number of enemy units, that is, no negative unit strengths. The TOWs would have killed a maximum of 24 tanks whether the enemy had 30 tanks out there or 300 tanks. The tankers could not kill more than 12 TOW teams because there were only 12 teams in the platoon. This makes sense because each weapon is directed against a particular target. These weapons usually kill only if a direct hit is made. Therefore, more targets don't make it easier to hit a particular target. It does make it easier to aquire new targets but Lanchester ignores this. If there were more than (16) TOW teams, then the next minute of combat could be simulated by subtracting the first minutes casualties from each side and then repeating the process that was done during the first minute. The attrition can continue until the units disengage or one side is completely wiped out.

Time step

The equations $dy/dt=-bx$ and $dx/dt=-ay$ are know as difference equations because $x(t)$ and $y(t)$ (the number of weapons) were assumed to be constant over a given time interval. Obviously the Anti-tank platoon did not have 12 teams for the entire minute of combat. The platoon gradually lost teams over the space of the minute. The

represent the fire effectivenes of the two weapons. The coefficients are the reciprical of the expected time required to kill the enemy target.

In our example lets assume that the TOW missile will kill every tank it hits and it will hit every time it is fired. The expected time required to kill a T-62 is then composed of three segments: the time needed to load a missile, the time required to acquire a tank and the time of flight of the missile. Now, if a trained crew can load the missile in about 5 seconds, acquire a target in about 10 seconds and the missile flight time is 15 seconds, the expected kill time would be 30 seconds. This would give a coefficient b=1 kill/.5min=2 kills/min. That is one TOW team will kill 2 tanks every minute. Given 12 TOWs and 33 tanks, 24 tanks would be wiped out in the first minute. That is in accordance with the equation dy/dt=-2x with x=12.

Now assume also that a good communist tank crew can kill a TOW jeep with a single hit. However, due to the long range, concealment of the targets, and poor target acquisition capabilities in a buttoned up posture, the T-62 requires 40 seconds to acquire a target and load, one second for flight time and 3 shots to achieve a hit. The expected kill time is 2 minutes, Which gives a coefficient of a=1kill/2min=.5 kills/min. [That is two tanks will kill one TOW team in one minute.] Therefore, in the first minute the tanks will kill 16 TOW teams. This is represented as dx/dt=-y/2 with y=33. This is more than the number of TOW

Equations		
	Heterogeneous	Homogeneous
Area/Indirect	155SP HOW.	Corps Artillery Group
Aimed/Direct	M60A3 Tank	Armored Division

Figure 1. Heterogeneous/Homogeneous Equations.

2.3 Aimed/Direct Fire, Heterogeneous.

The Lanchester equations involve the use of differential equations to model the change in the number of enemy weapons of each type caused by enemy action. To see how this works let us consider an engagement between a jeep mounted TOW anti-tank unit and a battalion of T-62s. Let $x(t)$= the number of jeep mounted TOW units at time t. Let $y(t)$= the number of tanks at time t. Both of these weapons fire in the aimed fire mode. The Lanchester aimed fire equation is based on the assumption that the number of casualties incurred on a weapons system is directly proportional to the number of enemy systems that are doing the firing. Mathematically this is represented as:

$$dx/dt=-ay \quad \text{and} \quad dy/dt=-bx,$$

where the proportionality constants a and b are known as the Lanchester attrition coefficients. These coefficients

Section 2. THE PRINCIPLES OF LANCHESTER-TYPE COMBAT MODELS

2.1 Types of Equations.

The JTLS CEP models ground combat attrition using fairly uncomplicated heterogeneous Lanchester equations which model the effect of each of a unit's combat systems against each of the enemy unit's combat systems.[2] This allows the model user to measure the attrition rates of each of his major combat systems separately. By contrast homogeneous equations, used in the Mcclintic Theater Model (MTM), measure the aggregate effects of an entire unit's weapons against the aggregate strength of all of the enemy unit's weapons.[3] The heterogeneous equations are slightly more complicated than the homogeneous equations because each combat system must be attrited by each enemy combat system separately which necessitates doing more calculations.

2.2 Types of Combat.

Two types of combat can be allowed in Lanchester attrition: area/indirect fire (mortars or artillery) or aimed/direct fire (tank guns, rifle fire or guided missiles) as shown in Figure 1. When only one type of fire is allowed, it is a simple heterogeneous Lanchester formulation. When both types of fire are allowed, it is a mixed heterogeneous Lanchester formulation and is used in the CEP.

GROUND COMBAT ATTRITION PROCESS

JOINT THEATER- LEVEL SIMULATION MODEL

SECTION 1 GENERAL

This report is intended to provide the average user of the Joint Theater-Level Simulation model (JTLS) with an explanation of the ground combat attrition process of the Combat Events Program (CEP). This report consists of a brief explanation of the principles behind Lanchester-type combat models, a narrative description of the ground combat attrition process, the rules followed by the CEP in the attrition process, and a detailed explaination of the Lanchester equations and attrition coefficients used in the CEP. This report is aimed at a user who is not familiar with Lanchester-type combat models and wishes to learn how the attrition process is carried out in JTLS.

The report also is intended to aid persons familiar with combat modeling in general and JTLS in particular to improve the ground combat attrition process. To this end, comments on possible weakpoints in the model have been included throughout the explanations of the attrition process and in the recommendation section.

UNCLASSIFIED

DATA BASE FOR ACCEPT P59

FWL COEFFICIENTS FOR COMBAT INDEX #40

SYSTEM #	COMBAT SYSTEM 1	2	3	4	5	6	7	8	9	10	11	
1	.0002	.0008	0.	.03	0.	.00004	.00032	.0034	.002	.0200	0.	.00
2	.0001	.0003	.0001	.002	.0001	0.	.00023	.0023	.004	.0030	0.	.03
3	.0003	.001	.0040	.500	.003	0.	0.	.004	.020	.0005	0.	.04
4	0.	0.	.0007	.03	.001	0.	.006	0.	0.	0.	0.	.05
5	0.	0.	.006	.03	.001	0.	0.	.003	.001	0.	0.	.00
6	0.	0.	.004	.0001	.0001	.0002	0.	.0002	.002	.0001	.006	.00
7	.0004	.001	.0009	.0012	0.	.0001	0.	.0003	0.	0.	0.	0.
8	.0001	.005	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	.0007	.0010	.0013	.0008	.0007	0.	0.	0.	0.	0.	.0001	0.
12	0.	.0001	.0003	.0002	.0002	.0001	.0001	0.	.0001	0.	0.	0.

COMBAT SYSTEM NAMES

NUMBER	BLUE NAME	RED NAME
1	M60A3	T64/T72
2	M113A.	BMP1
3	GRUNT (INF)	HUMAN WAVE (MR)
4	MORTAR	MORTAR
5	VULCAN	ZSU23-4
6	155SP	152 TOWED
7	TOW	SPANDREL
8	CLERKS& JERKS	WIMPS
9	GARBAGE	FILTH
10	RADIOS	SEMOPHORE FLAGS
11	CAS	CAS
12	COBRAS	FLYING TANKS

******NOTE: THESE ARE ONLY SAMPLES FOR ILLUSTRATION PURPOSES ONLY*****

FIGURE 2

RED
COMBAT INDEX

DAY-NIGHT 2 WEATHER 1

POSTURE	ATTACK	DEFEND	DELAY	WDRAW	MOVING	AVAIL	HASTY DEF	INCAP	WIPED OUT	WAITING
ATTACK	21	24	23	22	22	21	25	31	32	0
DEFEND	22	25	24	21	20	23	0	29	28	0
DELAY	26	22	0	0	0	0	20	0	0	0
WITHDRAW	21	22	0	0	0	0	0	23	23	0
MOVING	22	25	0	0	0	0	0	0	0	0
ADMIN	27	26	0	0	0	21	0	0	22	0
HASTY. DEFENSE	33	0	0	0	0	0	0	35	37	0
INCAPABLE	0	0	0	0	0	0	0	0	0	0
WIPED. OUT	0	0	0	0	0	0	0	0	0	0
WAITING	0	0	0	0	0	0	0	0	0	0

FIGURE 3

*****NOTE: THESE ARE ONLY SAMPLES FOR ILLUSTRATION PUROSES ONLY*****

3. Attrition Rules Summary.

1. A combat system may be either an indirect fire system or a direct fire system, but not both.

2. Direct fire systems use the Aimed-Fire Algorithm. Indirect fire systems use the Area-Fire Algorithm.

3. A combat system may cause attrition to an enemy system only if it is in range. Range is based on the distance between units (not between combat systems). Each weapon system has its own maximum range. which dominates?

4. Units that do not have sufficient ammunition may have some combat systems reduced to ineffectiveness. This factor is dependent on input data.

5. Units that are out of fuel may have some combat systems penalized in effectiveness. This depends on the input data.

6. A unit in combat with another unit may only use the fraction of its combat power oriented toward the hex side between them to cause attrition to the other unit.

7. No unit can lose more combat systems than it has operational.

8. Direct fire systems may kill (up to as many as) all the enemy combat systems. Indirect fire systems may also kill as many as all enemy combat systems, but the Area-Fire Algorithm is designed to kill only the enemy systems oriented toward the hex edge to which they themselves are oriented. Note: this discrepency within the CEP Area-Fire Algorithm is caused by the fact that the maximum number of casualties allowed is all of the enemy systems (just like for aimed fire). Thus, when the Area-Fire Equation calculates more casualties than there are enemy units, the unit loses all of its systems instead of only that portion facing the enemy as intended by the designers. ?x !!?

9. Units that are in a reinforcing role are not attrited in combat involving the reinforced units. Attrition against a unit does not affect any supporting units. Reinforcing units cannot give a unit support if they are themselves in combat (enemy units are in an adjacent hex).

10. An attritor unit faced with a hex containing more than one enemy unit divides whatever combat power it can bring to bear equally among all attritees.

Section 4 LANCHESTER ATTRITION EQUATIONS IN JTLS

The attrition equations used in the ATTRITION.CALCULATION routine can be considered the heart of the attrition process. This section is intended to explain the role of the equations and how they work in detail.

4.1 CEP Attrition Equations.

The attrition equations used in the CEP are just basic mixed heterogeneous Lanchester difference equations. The CEP uses difference rather than differential equations; approximation is used because an analytic solution to a differential equation is extremely difficult to obtain. The CEP assumes that the number of systems available to kill or to be killed is a constant over the assessment period. This allows the Lanchester equations to be treated as difference equations rather than differential equations. This approximation is acceptable for short assessment periods.

The Lanchester attrition equations used in the CEP are:

Lanchester Aimed-Fire Equation:

$$B_i = \text{minimum}\left(B_i,\ P_i * \frac{SR}{\sum_{j=1}^{m} Q_j * R_j * FR_j * AR_j}\right)$$

Lanchester Area-Fire Equation:

$$B_i = \text{minimum}\left[B_i,\ P_i * B_i * \left(\frac{SB_i}{SR}\right) * \sum_{j=1}^{m} Q_j * (R_j * FR_j * AR_j + S_j * FS_j * AS_j)\right]$$

Where

AR_j = Ammunition available switch 1=on, 0=off.

B_i = Number of blue systems of type i.

FR_j = Fuel effectiveness penalty 1=no penalty, <1=penalty.

i = Type of blue weapon system.

j = Type of red weapon system.

m = Total number of red weapon systems.

P_{SR} = Fraction of red unit sharing a hex edge with blue unit.

P_{SB} = Fraction of blue unit sharing a hex edge with red unit.

Q_{ij} = FWL coefficient j type system against i type system.

R_j = Number of red systems of type j.

S_j = Number of red systems of type j from supporting units.

4.2 Attrition Coefficients.

The equations require attrition coefficients(Q), the quantity of each of the attriting unit's combat systems(R), the quantity of each of the attritee unit's combat systems(B), the distribution of each units systems to their common hex side(P), and any penalties for fuel or ammunition depletion(FR, AR). The coefficients and the fuel and

ammunition depletion penalties are specified in the input data base. The distribution of the unit's combat power within its hex may be set by the player or by a default distribution set by the input data base. The quantities of each type of combat system for both the attritor and the attritee are initially set in the input data base and are updated later to reflect combat losses. Ammunition and fuel status is stored by the CEP and updated after each use of these supplies.

The attrition coefficients are stored in a three dimensional array that consists of 40 12x12 matrices that consist of one kill rate for each attriting weapon system (rows) against each attritee weapons system (columns). The routine WHO.DOES.WHAT.TO.WHOM uses the time of day, weather and the postures of both units to reference the COMBAT.INDEX array (Figure 3) to obtain a number that will determine which particular 12x12 matrix (Figure 2) is to be used to obtain the attrition coefficient for each set of attritor combat system and attritee combat system. A COMBAT.INDEX value of zero indicates that the attritor unit will not kill any of the attritee units. As an example, if both the units are in a withdrawal posture, the index would yield a value of 0 This would mean that attrition will not occur. Of course, the postures of the units could lead to a situation where one side can attrite the other, but the other unit cannot attrite the first unit. A non-zero index value is the number of the particular 12x12 coefficient matrix in the

3D array, FWL.COEFFICIENT (Figure 2). Since the COMBAT.INDEX is organized by day/night and weather conditions, these factors are not included in the coefficient array (Figure 3).

4.3 Fuel and Ammunition Penalties.

The ATTRITION.CALCULATION Routine accounts for the effects of ammunition or fuel depletion when it is calculating the number of combat systems that will attrit the enemy unit. A unit that is out of ammunition for a weapon system will have the effective number of that weapon system set to zero. This will prevent the system from inflicting casualties. A unit that is out of fuel may have the effective number of that system reduced a certain percentage if the system is fuel dependent. This is specified in the input data base. The effective number represents the equivalent number of weapons that the fuel penalty has reduced the particular combat system. A fuel penalty may be 20%, for example, reducing the strength of a 100 weapon combat system to the same strength as an 80 weapon combat system. A unit may cause attrition only with those systems that face the enemy unit. The number of systems that are facing the enemy hex are calculated for both sides. In addition the effective number of each combat system for reinforcing units are added to the corresponding effective number of the supported units combat systems. The

only values used in the actual attrition equations are the attrition coefficient, the numbers of the attritor systems and the numbers of the attritee systems.

4.4 Observations.

The number of casualties that is assessed cannot exceed the total number of that type system that the attritee unit has. The Analyst Guide states that the maximum number of casualties caused by area fire cannot exceed the number of the particular type of system that is oriented toward the common hex side. The actual coding uses the same maximum number of casualties for both the area and aimed fire algorithms. This maximum is the total number of systems. The actual maximum of all weapons in the entire hex is more realistic than the intended maximum of only the units facing the enemy. There does not seem to be any reason that the effects of indirect fire would be limited to the systems oriented toward the enemy hex. Unspotted fire can be used as a harrassment technique and a very heavy bombardment could possibly wipe out an entire enemy unit or at least some of the systems that are not oriented toward the common hex side. The ATTRITION.CALCULATION routine matches each of the attritors weapons against the attritee's combat systems.

It is important to note that the equations do not account for any increased vulnerability to an attritee system caused by fuel depletion. For example, a self propelled howitzer unit would be more vulnerable to counter

battery fire if it was out of fuel and could not displace to a new location. The same problem exists for ammunition. It is much easier to kill tanks with TOW missiles when the tanks cannot shoot back to suppress the TOW gunner. Neither the coefficients nor the equations take into account the effects on the attrition of the particular type of terrain where the combat occurs. The attrition process also does not reduce the effectiveness of units that have been in combat for a long time. The designers may feel that any decrease in combat effectiveness caused by factors such as wear and tear on the weapons or battle fatigue are balanced by the increase in combat power caused by the battle experience gained by the units.

Section 5. RECOMMENDATIONS FOR IMPROVEMENT

The improvements suggested in this section are restricted to the ground attrition routines in the CEP. As the CEP simulates ground attrition in accordance with the generally accepted principles of Lanchester attrition, it can be adopted "as is" unless extreme realism is required by the user. The ideal method for improving the model would be to team a combat arms officer with a programmer to review the model's ground attrition routines and insure that the assumptions and procedures made by the designers are reasonable from a military viewpoint. Some concepts that are common knowledge to a combat officer may not be evident to a civilian. programmer

5.1 Fuel and Ammunition Penalties Against Attrittee Units.

The JTLS attrition routine does not penalize the unit that is being attrited if it is out of either fuel or ammunition. Some combat systems are more vulnerable to enemy firepower when they are out of fuel or ammunition. Combat systems such as tanks or self propelled howitzers often rely on their mobility for much of their protection. SP howitzers usually displace to a new location after every fire mission to avoid enemy counter-battery fire. A unit that is out of fuel must remain stationary and becomes an easy target for enemy artillery. A unit that is out of ammunition may also be more vulnerable to enemy fire. An

M-2 Bradley IFV can hold off enemy armored vehicles beyond the range of the enemy's weapons by using its TOW missiles and its Bushmaster cannon. If it is out of ammunition, it is a relatively simple matter for the enemy vehicles to move close to the IFVs and destroy them. Tanks are much more vulnerable to anti-tank missiles when they cannot use their cannons to supress the enemy gunners.

The effects of ammunition and fuel depletion can be simulated mathematically in a manner similar to the way that fuel depletion is simulated in the current equations. A fuel depletion and an ammunition depletion factor could be added to the attrition equations. These factors would be part of the unit data base. If an attritee unit was out of fuel, the equation would multiply the combat power of the attritor weapon systems by a factor that was greater than or equal to 1. If the system did not depend on fuel for its protection (dismounted infantry for example), the factor would be 1 and it would not increase the enemy combat power. If the unit was more vulnerable when it was out of fuel, the factor would be greater than 1. If a tank was twice as vulneralbe to enemy fire when it was immobile, the fuel factor would be 2. The ammunition depletion factor would work in the same manner.

2. Reducing Combat Effectiveness Over Time.

There's a problem due to decreasing combat power.

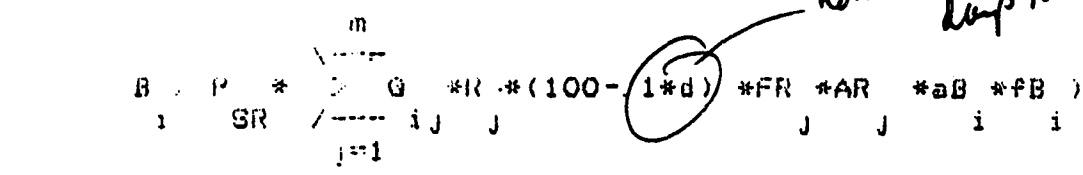
Units that are in continous combat with the enemy lose some combat effectiveness. This is because of the wear and tear of the weapons, battle fatigue, and leader casualties. A unit that is at 60% strength after enduring five days in contact with the enemy would not be as effective as a fresh unit that is at 60% of authorized strength. Each man in the fatigued unit would not be as capable or as motivated as a man in the fresh unit because he would be tired, dirty, and possibly sick. He would be less inclined to take risks or aggressively attack. His weapons would need maintenance to recover from the effects of five days of heavy usage. The unit would need a break of a few days to regain its fighting ability. The attrition subroutine does not model this effect on units that are in combat. The CEP only subracts killed or damaged weapons from a units strength.

One way to simulate a units' degraded combat ability would be to subract one percent of is firepower for each day it is in continous contact beyond one day. A unit that was in contact for five continous days would have its combat power multiplied by .96 to represent four days of one percent degradation. Eventually the unit will become totally ineffective regardless of the number of casualties that it recieves. This would encourage commanders to rotate units in order to maintain their effectiveness.

ified Lanchester Equations.

o simulate the attrition of units that are out
d/or ammunition and degrade a units combat
duration of combat time is to modify the basic
Section 4.
ified Lanchester attrition equations would be:

imed-Fire Equation:



$$B_i = P_i * SR_i / \sum_{j=1}^{m} Q_j * R_j * (100 - 1*d) * FR_j * AR_j * aB_j * fB_i$$

rea-Fire Equation:

$$B_i = P_i * SB_i * aB_i * fB_i * P_i * SR_i / \sum_{j=1}^{m} Q_j * (R_j * (100 - .1*d) * FR_j * AR_j + S_j * FS_j * AS_j)$$

AR_j = Ammunition available switch 1=on, 0=off.

B_i = Number of blue systems of type i.

FR_j = Fuel effectiveness penalty 1=no penalty, <1=penalty.

i = Type of blue weapon system.

j = Type of red weapon system.

m = Total number of red weapon systems.

P_{SR} = Fraction of red unit sharing a hex edge with blue unit.

P_{SB} = Fraction of blue unit sharing a hex edge with red unit.

V_{ij} = FWL coefficient j type system against i type system.

R_j = Number of red systems of type j.

S_j = Number of red systems of type j from supporting units.

JTLS USER ACCEPTANCE TEST COMMENTS
as of 271400 June 1984

GENERAL FUNCTION COMMENTS

I.2.1 Player De-Emphasis

. Air play is extremely player intensive since it is modeled at he individual aircraft system level. An Army agency would equire Air Force augmentation to use JTLS or would not be able o play the air war properly. The resolution of the model is nbalanced between air, which is modeled at the individual ircraft weapon system level, and ground, which is modeled at the nit level (during the test, ground units were normally brigades r higher). The higher resolution modeling of the air assets ppeared to contribute to the extremely slow speed of the model. urther user definition of model resolution level is required for he contingency analysis, educational, and training purposes of TLS.

ENERAL FUNCTION-GENERAL

. Weather is assumed to be clear and calm. If other weather is esired, the Controller must manually change the weather arameter. Other types of weather are permitted, however, each ype requires a new set of Lanchester attrition matrices for round attrition and modification parameters for air sensors and eapon systems. Weather does not effect national, strategic, or UMINT sensors nor does it effect ground movement rates. Weather hould be modeled as a stochastic variable. This could be ccomplished by a database entry of the probability per time eriod in the theater of each type of weather. A random number ould then be drawn every 12 or 24 hours to determine what type f weather is current. Without this modification, weather will ost likely remain clear and calm. Also, the movement algorithm hould be modified to include a weather decrement factor for ovement time. Further consideration should be given to ncluding weather decrement factors for the intelligence systems ther than air.

. JTLS models some of the effects of Nuclear and Chemical eapons but does not model release requests or permission. The odel should include player request for release and controller ermission for use with appropriate time delays for the theater. o nuclear or chemical weapons should be allowed to be employed y the model until the release order has been given.

Functions	Total	Manditory Items		Optional Items		
		Imple-mented	Not Imple-mented	Imple-mented	Not Imple-mented	Not Observable
General Functions	32	17	3	4	2	6
Ground and Naval Functions	38	26	4	3	2	3
Air Functions	56	51	4	0	0	1
Logistics Functions	34	26	1	2	4	1
Intelligence Functions	11	3	2	1	3	2
Controller Functions	13	11	0	2	0	0
TOTAL	184	134	14	12	11	13

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ures:

1. Participants
2. Evaluation Check List
3. Suggested Changes
4. Implementation of User Specifications

8

minimum for continueal testing, with higher speeds red for JTLS to be fully usable by its sponsors.

. Level of Resolution.

here is a need for the users to define the priate level of modeling resolution for each ional area of JTLS. Air assets are modeled and ted at the individual weapon system leve., while d units are modeled at the level of combined arms . Intelligence assets, except for the USAF, are gated to the functional area level. The ligence players cannot, as a result, create and te collection plans. They cannot issue specific ngs or properly analyze the results of lilgence assets activity. Army helicopter tions also require remodeling to properly reflect unique capabilities and employment. The ground movement algorithms and player commands must be ied to allow for more positive control of movement routes and unit sequencing.

. Data Base.

he contractor has successfully removed all data the model code as required by the requirements ent. During testing, JTLS has proven to be tive to data base inputs, particularly the infantry tion coefficients. The users must define more sely what each each item of data describes, specify nput parameter ranges, refine current data and er test the model sensitivity to data inputs. A data element dictionary is needed.

. Naval Functions.

ase line naval modeling reuirements have been d in a way that is very narrow in scope. TRo ain a joint modeling perspective, priority should ven to adding naval capabilities when future operat modeling enhancements are considered. Elaboration existing naval functions and the addition of bious operations is required, particularly those capabilities that impact on the land battle.

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ort

TOTAL XXX

CRITICAL AREAS

The following paragraphs discuss those areas where S, in the opinion of the evaluation team, requires ediate improvement. These areas are noted in light the general criteria noted in Paragraph 6 and are not essarily tied to the detail of the functional uirements document.

a. Scenario Preparation Program.

The Scenario Preparation Program was not used to ate a data base for this test. The program failed ing the preceeding SPP test when an attempt was made load the full classified data base and when wrongly natted items of data were entered. At present, only Jet Propulsion Laboratory has the knowledge and ipment to prepare a data base for JTLS. While tware is to be provided to enable a user to enter a a base manually or from computerized data, manual will be slow. To manually prepare the data base the scenario used in this test would take an imated one man year. This feature makes the Scenario paration Program unsuitable for quick response lysis of unexpected contingencies at this time.

b. Model Speed.

The ratio of time simulated in JTLS to actual clock was far less than four to one. In order to be most ective, the game must operate at various speeds that controlled by the user. The current design allows allows for game operations at various speeds, as ted in the requirements document. There is no rance, however, that the game and players will ally be able to achieve these maximums. The design l of four game hours to each real hour, as defined by users, has not been met during testing. Many tors contribute to actual game speed ratios which are gely dependent on the given scenario. While hardware software options exist to speed up the game, we not be sure what their effect will be. Both Con ts Analysis Agency and the War College have expressed need for achieving a speed ratio of at least 24:1. users must decide on what changes to JTLS are ceptable to increase overall game executioon time, still maintaining an acdeptable level of model olution. It is apparent that the design goal of 4:1

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The following observations relate to the general teria described above.

a. Quality.

Mean Time Between Failures	3 hrs, 5 min
Mean Time to Repair	2 hrs, 18 min
Total Run Time	49 hrs, 13 min

b. Playability.

Game Time:Clock Time Ratio	2.53:1

c. Realism.

Casualty Rate	?/1000/day
Rate of Advance	+/-10 km/day
Aircraft Exchange Rate	X:1

SPECIFIC FINDINGS

The following statements summarize the observations the players and the evaluation team about whether the ıtures asked for in the user specification document 'e present or not.

a. Of the manditory items that could be observed by) players or team, 91% were implemented as described the document.

b. Of the desirable items that could be observed, % were imple mented as described.

c. Of the total requirements as described in the :ument, 13% could not be evaluated by the players or ım as either implemented or not.

RECOMMENDED CHANGES IN THE SIMULATION

Players submitted sheets describing deficiencies in ılism in JTLS that should be changed. The number of :h changes by component of the simulation are mmarized below, and they are listed in detail in :losure 3.

Data Base	XX
Scenario Preparation	XX
Combat Events: Ground	37
Combat Events: Air	27
Combat Events: Logistics	XX
Combat Events: Intelligence	XX
Controller	XX

ndividual JTLS programs and subroutines has been onducted already with sponsor participation in the irst three functional validation tests.

b. Scenario. The test involves a theater level ampaign with 114 units on one side and 89 on the other ith combat starting at D+50. The campaign involves 23 ivisions on one side and two and one third divisions on he other.

c. Phases. Phase I was run primarily to permit layer familiari zatrion by JPL. It involved using the ull scenario data set from game day zero to D+50 in hich there are is no combat. Primary items to be valuated during this phase include TPFDD events, LOGIN vents, Unit move ment and normal consumption of upplies. Phase II involves the full use of the ntegrated system employing all 10 terminals and 27 layers.

d. Evaluation. The user requirements were ransferred to rating sheets, one of which was given to ach player. Each player rated each requirement as aving been observed as being met, not being met or not bserved. These ratings were tallied as described elow. Where there was disagreement among the players, he evaluation team arrived at its own assessment.

GENERAL CRITERIA

In interpreting the player evaluations, the valuation team was guided by the following general riteria:

a. Quality. Did the software in the model work ell enough that it could be used and revised in the uture?

b Playability. Did the model work well enough to e used for driving field exercises and evaluating ontingency plans in a reasonable period of time with he players likely to be available?

c. Realism. Did the model's simulated results look ike a realistic war?

GENERAL FINDINGS

the acceptance test were essentially "big bang" type tests that involved full play of JTLS to find out whether specific programming features worked and what bugs would arise that caused systems failure. The first three functional validation tests were used to run individual modules of the simulation. During all tests model defects that were discovered were corrected on the spot.

e. Present Test Purpose. The functional validation tests were not intended to determine whether design specifications had been met or whether JTLS is a useful tool for its sponsors. The acceptance test is intended to provide the data with which to do both.

4. TEST ADMINISTRATION

a. Location: Center for Land Warfare
Army War College

b. Dates: 18 thru 29 June, 1984

c Participants.

Readiness Command	16
Central Command	4
Pacific Command	1
Army Concepts Analysis Agency	3
Army War College	7
Air War College	4
Military Academy	1
Jet Propulsion Laboratory	10
Contractors	3

(See Inclosure 1 for names.)

d. Test Director: Colonel Leighton O. Hasselgrove

e. Hardware Employed. VAX 11/780 computer, two disc drives, ten VT102 terminal, four megabytes of internal memory, a Graphover 9500 graphics system and a Sony 25" television monitor.

5. TEST PROCEDURE

a. General. The test is designed as a general, macro-level evaluation of the totally integrated JTLS system. This approach was selected because testing of

c. USREDCOM Contingency Planning Subtask (CPS) Joint Theater Level Simulation (JTLS) Functional Specification. Pasadena, California: Jet Propulsion Laboratory, February 29, 1984.

d. "CAA Candidate User Acceptance Test Criteria." Bethesda, Md: Army Concepts Analysis Agency, 5 August 1983. [printout]

3. MODEL SUMMARY

a. Description. JTLS is a stochastic, two-sided, player interactive simulation of combat and logistics for ground, air and naval forces in a theater of operations. It was designed as an elaborated version of the McClintic Theater Model of the Army War College. It is to be used to "drive" joint service training exercises and to analyze contingency plans. JTLS consists of 110,400 lines of executable code and 1014 modules, a very large simulation. It uses four terminals per team; one each for the air, the logistics, the intelligence and the ground-naval player.

b Designer. JTLS is being built for the U.S. Readiness Command the Army War College and the Army Concepts Analysis Agency by the Jet Propulsion Laboratory in Pasadena, California.

c. Design Specifications. JTLS consists of approximately 110,400 lines of executable code and 1014 modules, a very large simulation. The three sponsors have specified 187 design features desired in the final model (Par. 2.b.). The contractor's statement of what he intended to accomplish is contained in a separate document (Par 2.c.). These requirements are summarized below:

Data Base Preparation	7
Start/Restart Module	3
Model Interface	10
Combat Events	164
TOTAL	184

Additional specification items including those related to graphics, hardware and documentation have been formalized in a separate document (Par. 2.d).

d. Previous Testing. Four functional validation tests have been conducted previously from October through May 1984. The final functional validation and

DRAFT
FOR DISCUSSION PURPOSES

U.S. ARMY WAR COLLEGE
Center for Land Warfare
Carlisle Barracks
Carlisle, Pennsylvania 17013

29 June 1984

SUBJECT: Joint Theater Level Model User Acceptance Test Report

1. TEST GOALS

The user acceptance test is the culmination of the JTLS Phase I development effort. The goals of the test are to:

a. "Provide a means by which representatives of the three sponsoring agencies, USREDCOM, US Army War College and US [Army] Concepts Analysis Agency can exercise, observe and evaluate JTLS capabilities."

b. "Insure that the requirements as stated in the JTLS User Functional Requirements (Baseline) Document (JPL D-449) have been satisfied."

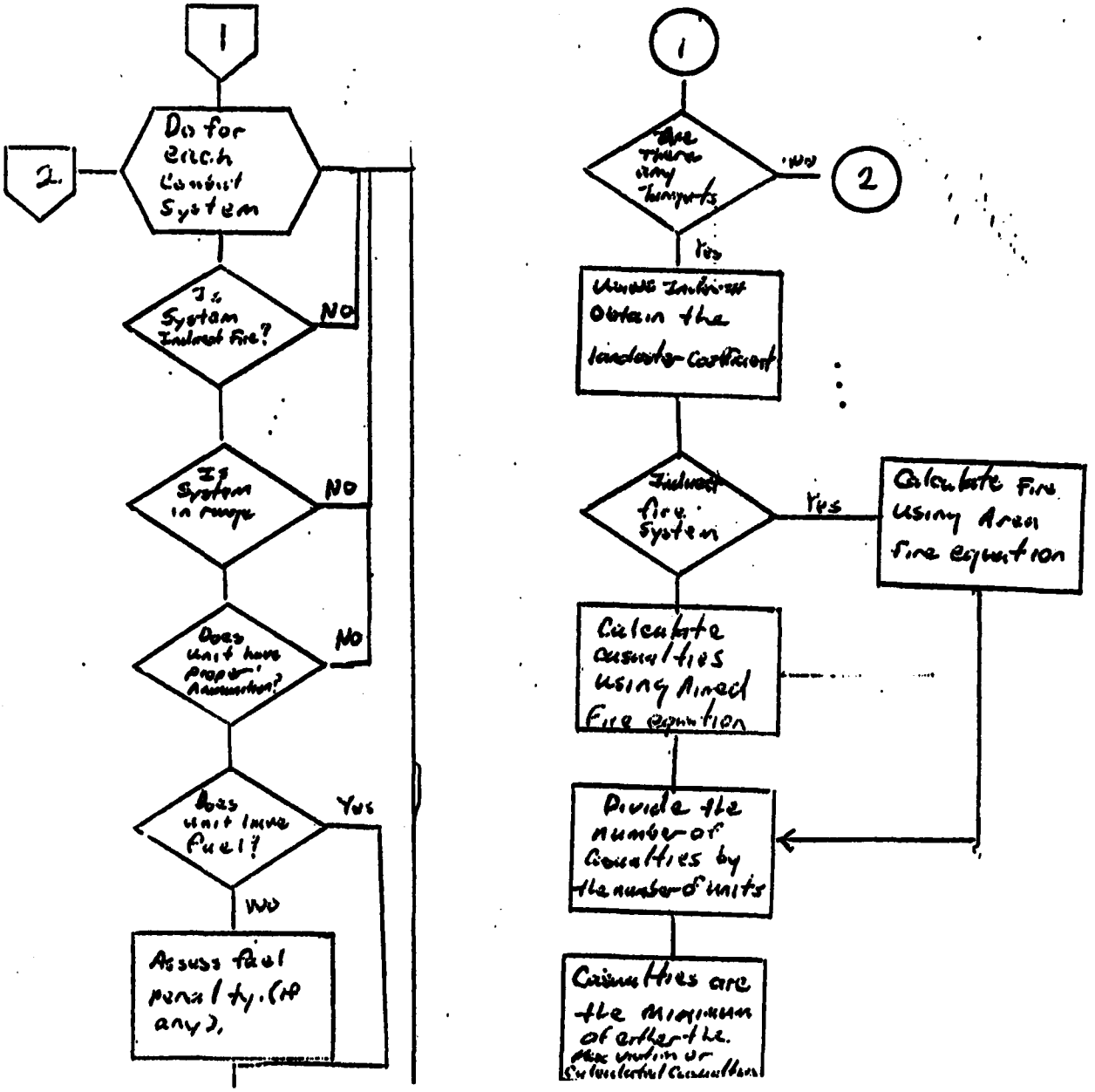
c. "Determine if the JTLS system, as delivered by the Jet Propulsion Laboratory (JPL), is acceptable to the sponsors." (Ref. 2 a.)

2. REFERENCES

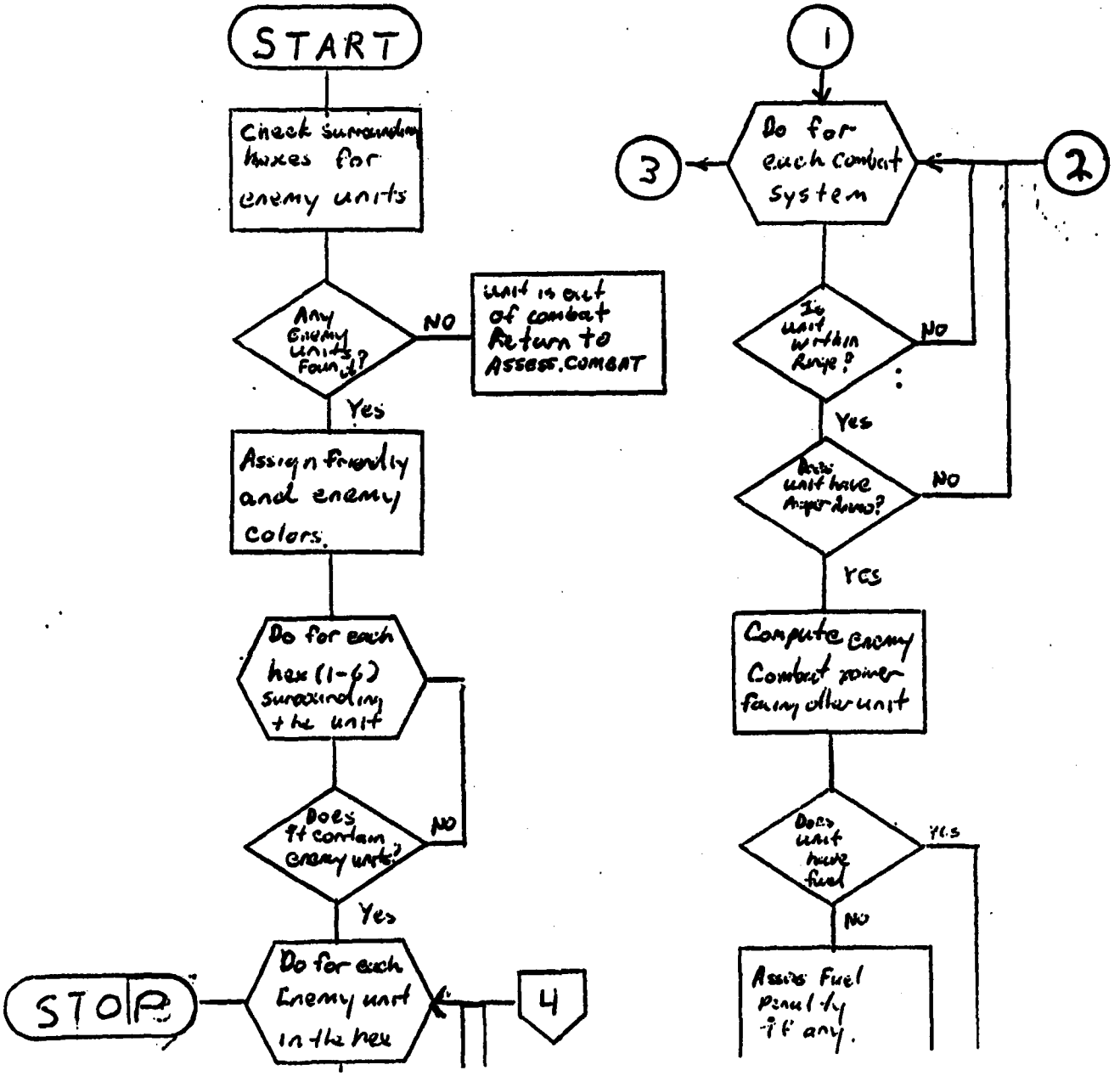
a. "Joint Theater Level Simulation (JTLS) User Acceptance Test Plan." US Readiness Command, June 9, 1984 SECRET

b. R. Roland, E. Roland and E. Kelleher, Jr. Contingency Planning Subtask (CPS) Joint Theater Level Simulation (JTLS) User Functional Requirements (Baseline). Pasadena, California: Jet Propulsion Laboratory, May 6, 1983.

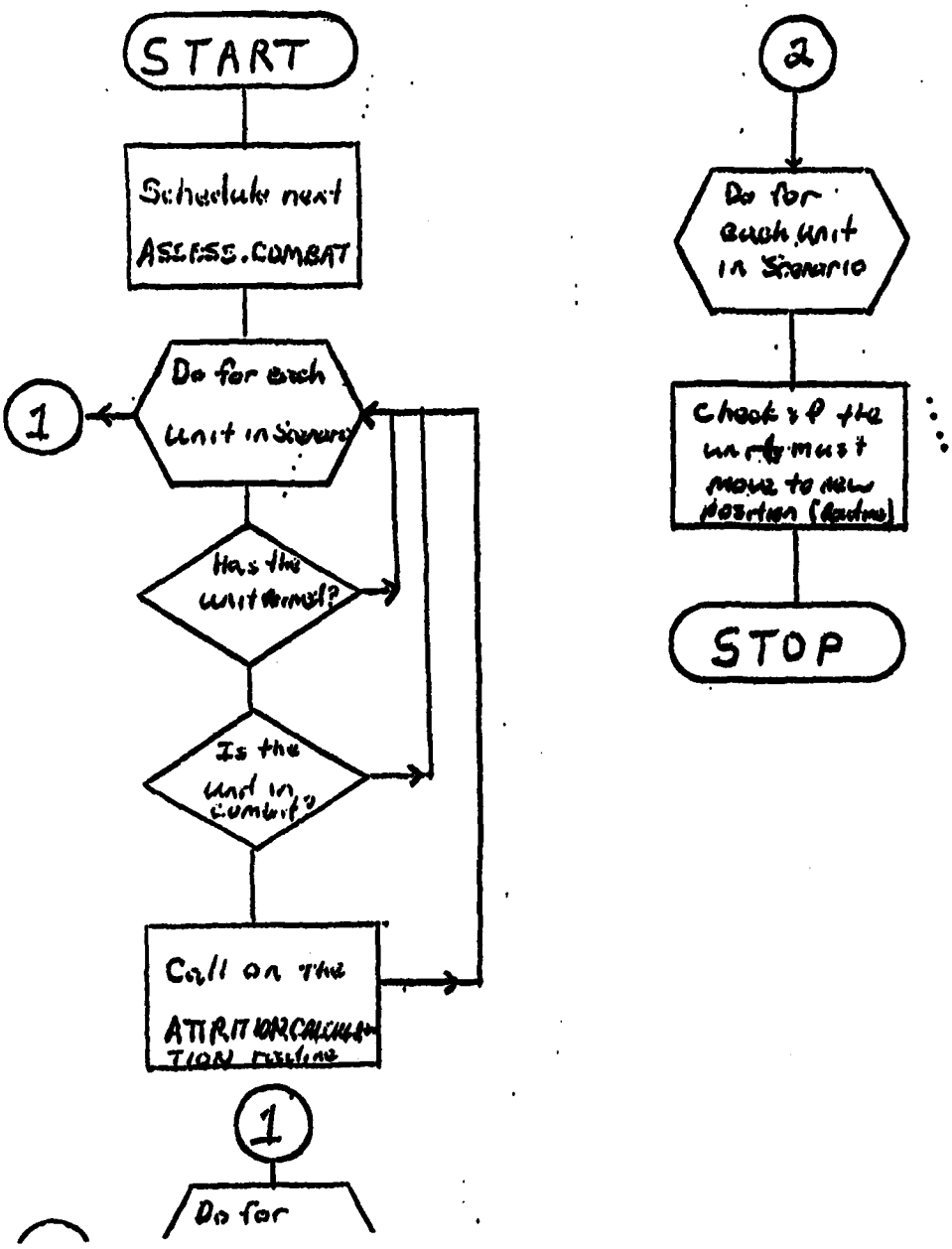
Incl 3


1
Do for each Combat System
2
Is System Indirect Fire?
NO
Is System in range
NO
Does unit have proper ammunition?
NO
Does unit have fuel?
Yes
NO
Assess fuel penalty. (If any).
1
Are there any Transports
NO
2
Yes
Using Indirect Obtain the Incidents Coefficient
Indirect fire System
Yes
Calculate Fire using Area fire equation
Calculate casualties using Aimed Fire equation
Divide the number of casualties by the number of units
Casualties are the minimum of either the Max Uniform or Calculated Casualties

ATTRITION.CALCULATION



ASSESS.COMBAT



f = Attritee fuel depletion penalty, 1= no penalty,
>1= penalty.

a = Attritee ammunition depletion penalty, 1= no penalty,
>1= penalty.

d = number of days in continuous combat above 1 day.
$(100-1d)$= the penalty assessed.

GROUND FUNCTION COMMENTS

AP.5.0 Land-Related Functions

a. Players should have the option of giving units with a WITHDRAW or a DELAY mission an order to destroy all bridges on their route as would be common in these type operations.

AP.5.1 Combat Engineer Support System

a. In addition to the currently modeled functions of lay or clear minefields and repair damaged targets, ground units should be capable of mobility enhancement engineering functions such as road improvement and bridging obstacles. This routine should check for the appropriate supplies and the current activities of the unit which may take precedence over the engineer function.

AP.5.1.1 Minefields

a. Minefields should cause attrition to units that enter a mined hex without first giving a CLEAR MINE order.

b. Attrition and movement delay caused by a minefield should be proportional to the amount of mining done in the hex by ground and artillery units. Currently only one density of minefield is modeled.

c. Supply category mines should be decremented when a minefield is layed to force logistics players to manage this asset.

d. Players should be able to override a unit clearing an enemy minefield before leaving the hex. This is a valid default procedure but may not be appropriate based on the unit's mission.

e. Players should be able to direct a unit to mine adjoining hexes without the entire unit moving to the hex and dumping extra supplies to accomplish the move. At the current level of ground unit resolution, the entire unit would not execute the mining of nearby hexes.

AP.5.2 Unit Movement

a. Movement time through a hex is currently degraded for the number of friendly units in the hex (square root of 1+number of units). Movement time should also be degraded by the number of supply convoys in the hex and refugee movement if appropriate. Refugee movement could be modeled similar to supply movement and defined by the players or controllers.

b. The route optimization algorithm considers only speed of movement. Units will, therefore, move over the quickest route which may well be the most likely target for interdiction, e.g. the only bridge over a river. The algorithm should include a check for known, in range enemy units similar to the air algorithm check for ADA sites.

c. Players had difficulty in specifying routes that the units would follow in the game. Some of the discrepancy seemed to arise from the hex system which the players do not see. The problem was particularly noted when trying to pass units through narrow obstacles such as a mountain pass or over roads which showed on the map, but apparently were not in the database.

d. After movement orders, some supporting units would bypass their supported combat unit and lead them into combat. Some logic similar to the follow-on option, modified to allow a supporting mission, should solve this problem.

AP.5.3 Non-linear Attrition

a. Attrition rates for some weapons should be a function of terrain, e.g. DPICM is less effective in forested and urban terrain than in open.

b. Attrition rates should be a function of defender's time in position. This would account for a unit's ability to fortify its defenses over time and could be modeled through a fractional degradation factor that varied inversely to the time in position.

c. The indirect fire algorithm currently attrits only that portion of the enemy unit which shares a hex edge with the attriting unit. Conceptually this is incorrect. An area fire system, e.g. artillery, can fire throughout an adjoining hex since most artillery systems have a range of at least 24km. In a similar manner, the direct fire algorithm is conceptually incorrect. Direct fire weapons attrit enemy thoughout the hex rather than just on the hex side shared with the friendly force. These current artificialities were created to prevent a clever distribution of unit strength from stopping movement of a superior unit. This could occur by placing a very small percentage of unit strength toward the enemy. When a database is created, however, the true meaning of the attrition coefficients must be kept in mind. For instance, in this case, the coefficient represents the rate at which one artillery piece in a force faced with a similar target array would attrit the various types of target weapon systems within the enemy array. The explicit fire mission attrition algorithm appears to be conceptually correct.

d. Reinforcing units should be subject to attrition of those weapons systems which are affecting the reinforcement. This would represent counter-battery fire. In a similar respect, units which execute point fire missions should be subject to attrition.

e. Units which are out of fuel and/or ammunition currently are degraded in their ability to attrit the enemy. In a similar manner, units which are out of fuel and/or ammunition should be attrited at a faster rate since they cannot respond to combat in the same manner as a totally capable unit.

f. The combat effectiveness of units which have been in continuous combat should gradually degrade over time. This can be done through a fractional multiplier to their attrition coefficients. When the unit exits combat for a period, e.g. 24 hours, its attrition coefficients should be restored to full value.

g. The players were uneasy with the attrition resulting in the model. Their subjective analysis was that personnel attrition was too high while combat vehicle attrition was too low. This is an obvious and fruitful area for further research.

AP.5.4 Air Defense Improvement

a. The model assumes perfect IFF and therefore no friendly aircraft destruction by friendly air defense. Realistically, there will be a small percentage of friendly aircraft destroyed by their own air defense systems.

b. Attrition rates of aircraft should be a function of altitude envelopes. Nap of the earth flights would have higher survivability, but a lower probability of detecting targets.

c. Players cannot move air defense sites since they are categorized as targets. The players should be able to order an air defense site to move and the movement should be modeled as a ground convoy.

AP.5.5 Target Specific Units

a. Players should be able to define targets which were not included in the original database. Some minor bridges or roads across terrain features could not be targeted for destruciton or interdiction since they wre not defined as targets.

b. Players should be able to order interdiction or destruction of targets that are catergorized as their own color. This would allow units to destroy targets as they pull back and would not require the time delay of contacting the controller to change the target type.

AP.5.6 Indirect Fire Missions

a. An artillery unit which is in a reinforcing mission should have an upper limit on the ammunition it expends on that mission.

b. An enhancement is needed in chemical and nuclear attrition to reflect the MOPP posture and/or capability of the units. Also, when a unit is in MOPP, movement rates and weapon effectiveness should be degraded.

c. An enhancement is required in nuclear attrition to create rubble and obstacles and to attrit weapon systems.

BP.5.3 Opposing Forces in Same Hex

a. Airdrop and sealift cannot be placed in an occupied hex. This negates amphibious and airborne/airland capabilities.

BI.6.0 Sea-Related Functions

a. Strategic sealift is not modeled. MTM was capable of this function.

b. Sealifted units are not attrited when their carrying ship is damaged.

c. There is no check on ship capacity versus the size of a sealifted unit.

d. Ships are never destroyed. When they are damaged sufficiently, their movement rate is slowed.

e. Sealifted supplies are not destroyed or damaged when their ship is damaged.

f. Damage to an aircraft carrier does not prevent it from launching aircraft.

g. Subsurface and ASW is not modeled.

h. The aircraft carrier routine does not check compatibility of the landing area and the aircraft.

GROUND FUNCTION-GENERAL

a. The Infantry units of the 101AA and the 82ABN Divisions are not modeled to depict their inherent airmobility. Reaction times to an air move order are too slow.

b. The 6CBAC is currently modeled as a tactical air unit. This is incorrect. CBACs should be modeled as ground units with unique characteristics such as the ability to conduct screening operations or delaying operations over extended distances without becoming decisively engaged and to conduct deep raid and harrassing operations.

c. Air cavalry modeling can be improved through the use of air scouts and the QRA.OAS mission. An air scout could be sent to a hex and modeled like a HUMINT Team that can see its hex and the six adjoining hexes. A team of attack ships could then be placed on QRA.OAS to support the scout. When the scout detected targets, the attack helos would scramble and attack the target.

d. The database entries for Special Forces should be reviewed. Particularly the attrition rates and the movement rates seemed low.

e. The model did not accept in all routines a change of unit headquarters-subordinate unit relationship.

AIR FUNCTION

AP.4.0 Air Operations

a. One Wild Weasel weapon shuts down the air defense capability of an entire hex. It should only shut down the targeted ADA site or a percentage of the ground to air attrition of a unit. An entire division's air defense assets would not shut down due to the presence of one Wild Weasel.

AP.4.3 Flight Routes

a. The flight route planning algorithm should not give friendly ADA sites equal avoidance weight as enemy sites.

AP.4.7 Aircraft Carrying Capacity

a. There should be a check for outsized cargo, e.g. tracked vehicles, versus aircraft type to prevent improper cargo in an aircraft.

AP.4.8 Cargo Load Table

a. Two or more aircraft units should be able to be assigned to airlift one ground unit. Currently only one air unit can be used and it shuttles until the ground unit is moved.

AP.4.20 Aircraft Capability and Loading

a. An enhancement is needed to reflect hardened shelters at an airfield in the vulnerability of the aircraft parked at that airfield.

AP.4.23 AWACS and Tanker Withdrawals

a. AWACS currently has perfect knowledge that it has been detected by the enemy which allows it to immediately depart the area. This should be reduced to a probability.

AIR FUNCTION-GENERAL

a. An enhancement is needed to reduce the maintenance, refuel, and rearm rate of an airfield which has suffered conventional, nuclear, or chemical attack, or is in MOPP.

LOGISTICS FUNCTION

AP.7.0 Logistics-Related Function

a. The supplying unit in the CROSS LEVEL command should not give up weapon systems unless specifically ordered by weapon type.

BP.7.6 Transportation System

a. Replacement units and follow-on units arrive at the current location of the parent unit, not a port or airfield. They should arrive at such a facility thereby requiring incountry transportation, loading the transportation network, and being subject to attrition during movement to their parent unit.

LOGISITICS FUNCTION-GENERAL

a. Disgarded supplies disappear from the model. They should remain for use by units which later occupy the hex unless the disgarding unit suffers a time penalty and destoys the supplies.

INTELLIGENCE FUNCTION COMMENTS

AI.1.4.3 Player Book

a. Red unit information, similar to the blue unit information, should be included in the intelligence player book for the opposing side. That information would normally be available prior to hostilities. The information could be degraded by a certain percentage.

AP.8.2 SLAR

a. Army Corps level sensors, e.g. SLAR and ELINT, are not explicitly modeled. These assets are implicit in the strategic intelligence detection probability. These assets should be played at least to the level of being tasked to surveil a specified area for a specified time period and report at specified intervals to the stategic intelligence algorithm which will combine this intelligence with the overall intelligence list. The current modeling of these assets ignores the function of the intelligence staffs to manage assets and the scarce nature of these assets. It also ignores the rewards for concentrating the assets on certain areas of high interest.

AP.8.3 Ground Sensors

a. Tactical intelligence assets (organic to ground units) are modeled with a single detection range for all ground systems in the unit and another range for all air systems in the unit. These ranges should also be a function of terrain, weather, and light conditions as appropriate to the sensors in the unit. As a minimum, the detection range of the ground units must be a function of terrain in the adjoining hexes.

b. Tactical intelligence assets currently report only when queried. Players should be able to input a periodic intelligence

report parameter that would cause the tactical intelligence routine to report detections it has made since the last report, either to the player or merge these findings with the strategic report. An alternative would be to summarize the reports at division level and print them out with a division identifier.

AP.8.4 HUMINT

a. HUMINT Teams should be subject to attrition. This could be modeled by drawing a random number at the end of their mission to determine if they successfully returned or were destroyed.

b. There should be a data input for the reporting range of HUMINT Teams to reflect their communications range.

c. HUMINT Teams should store all intelligence reported since their last report and report this. Currently the teams only report what is in the hex at the time of their report. If the team detects an airfield, the number and type of aircraft at the field should be reported.

d. The HUMINT Teams should have a probability of detection since they would not be able to detect everything in a 8 km radius.

e. The 30 minute status report from the HUMINT Team should contain their departure time from the current hex. If the player created an identifier for the HUMINT Team, the identifier should appear on the status report. The teams should report to the players when they have returned to their parent unit.

f. Players should have the ability to change the HUMINT Team mission once it is position by curtailing or lengthening the time in position or defining additional hexes to surveil after the current hex mission is complete.

g. Parent unit SITREPS should include the number of HUMINT Teams available for assignment, or the total number and the number deployed.

BP.8.1 Intelligence Summarization

a. The volume of information in the summaries requires some key to that information which has changed from the last report. An asterick should mark those units who's location or posture has changed since the last report.

b. The current strength column should only read to two decimal places rather than five.

c. RECCE report content should include aircraft on board by number and type for any airfields which are reported.

BP.8.2 Jamming

a. Enemy EW coverage of a hex should degrade strategic and tactical intelligence detection probabilities in that hex. A simple multiplicative degradation would be sufficient.

BP.8.4 Reporting

a. Message Queue procedures hinder rather than facilitate dissemination of intelligence. Recommend the following changes:

1. Prioritize messages by standard communications procedure, e.g. FLASH or ROUTINE.

2. Within precedences, use the last in first out method to send the messages. Thus all FLASHES take precedence over IMMEDIATES, however within the classes, the latest message takes precedence over the others.

3. There should be a screen recall utility for filed messages to allow further editing before printing.

4. Depending on memory space, allow the players some work file space to word process items for the game and print them.

5. The scan command should have an option to scan all messages in a file rather than specifying the number in the file.

b. Realistically, there would be intercept of such things as enemy SITREPs and intelligence reports. Recommend consultation with a SIGINT expert concerning this entire concept and modeling of the capability with appropriate probability of intercept.

INTELLIGENCE-GENERAL

a. Joint Command should be able to task national and strategic assets with an ability to specify: point or area target (point, strip, or polygon), report interval, and duration of the requirement. Additionally, reaction time to include collection, collation, and reporting delays, should be included. A realistic constraint should be placed on the total number of simultaneous taskings on these assets. The players should be able to alter or cancel these taskings at any time.

McCLINTIC THEATER MODEL

GROUND ATTRITION PROCESS

Engineering Research Project Report

By Cadet John S. Morris III

TABLE OF CONTENTS

I. INTRODUCTION.

The McClintic Theater Model (MTM) has been the subject of the USMA And Army War College (AWC) Model Validation Program (MVP). The purpose of MVP is to assist the AWC in providing combat model users with "confidence statements" about the outcomes obtained from MTM. This particular project analyzes the effects of key input parameters on the ground combat subroutine.

II. PROBLEM DEFINITION.

The MTM ground combat subroutine uses a simple homogeneous Lanchester equation dependent upon the modified strengths of the attacker and defender to produce attrition. The aim of this project was to determine how each of the input parameters modified the strengths of each combatant before the attrition was calculated and modified the resultant force levels as a function of time.

III TEST METHODOLOGY.

I investigated the effects of each of the eight input parameters identified by Cadet Bentley and Cadet Entner in their reports. These parameters are listed and briefly explained below.

UNIT STRENGTH: This is a real number that indicates the relative combat power of a particular unit. The values in the Nato database (provided by AWC) range from 1.0 to 6.0. This is the parameter that is reduced as a result of combat.

UNIT TYPE: This describes what type the unit is such as airborne, air force or armor. These serve to determine

which actions are feasible for a unit to undertake. This can result in unrealistic combat results if certain types of units engage each other. For example, if an air force unit is attacked by an armor unit, the air force unit should be easily destroyed by the armor unit in ground combat regardless of the strength of its fighter aircraft represented by the Unit Strength parameter. The game also fails to take into account Unit Type in assessing terrain modifiers. An infantry unit would derive a greater terrain benefit from urban or forested terrain than armor units which perform best in less restricted terrain.

ENGAGEMENT TYPE: This parameter describes whether the units in combat are considered moving or in position at the moment of contact.

TIME IN POSITION: This includes how long the units have been in position before combat and how long since combat has started. This determines the defensive postures of the units. The postures are: deliberate defense (in position more than three hours for red units and in position more than 72 hours for blue units), hasty defense (in position between one and three hours for red units, three and 72 hours for blue units) and meeting engagement (in position less than one hour for red units and less than three hours for blue units).

AMMO AVAILABILITY: A 0/1 variable that records if the unit has any ammunition.

POL AVAILABILITY: A 0/1 varible that records if the unit has any fuel.

MINEFIELD/CONTAMINATION EFFECTS: This is the attrition that occurs when a unit is in a mined hex or a hex contaminated by nuclear or chemical weapons. The ground attrition subroutine does not include the effect of the initial attack, but it is included in a separate subroutine.

TERRAIN EFFECTS: This is the effect of different terrain types on the attrition rates.

UNIT ORIENTATION: This refers to how a unit's combat power is distributed within the hex it occupies. A given percentage may be devoted to each hexside.

The effects of each of these input parameters was determined by both experimental analysis and analysis of the combat subroutine programming code. The object of these analyses was to determine whether the parameter affected combat as predicted by the source code and the game manuals.

The experimental analysis involved conducting four separate battles simultaneously in each game run. Four battles were used to save time. A Soviet Tank Division attacked a West German Armored Division in each battle. Each red-blue pair was placed two hexes apart in an isolated part of the map. In each run the red (Soviet) unit would move into a hex adjacent to the blue (W. German) unit and combat would begin. All of the input parameters were held constant except the parameter under investigation. The experimental output was the attrition experienced by each unit. This would be analyzed to determine how each input parameter affected combat.

Initially it was planned to conduct multiple runs of

each experiment to determine the statistical variance of the results. This proved unnecessary when all runs of the initial sets of experiments were exactly the same. Regardless of game time, starting time or game speed as long as all input parameters are the same, the combat results would be the same also. A subsequent analysis of the entire combat subroutine revealed that there were not any stochastic elements involved in the entire attrition process. All combat strength modifiers were determined directly by the values of the input values. All random combat attrition is a result of variations of the input parameters by the player or by other subroutines. An example of this would be a situation where bad weather delayed the arrival of an attacking unit long enough to allow the defending unit to assume a deliberate rather than a hasty defensive posture. This would result in greater attrition for the attacker than normal. This made multiple runs of each experiment unnecessary. Only two runs would be made of each experiment to insure that the results were correct.

The source code for the combat subroutine was examined to predict the effects of each input parameter and to explain any unusual results. After much careful examination the attrition process became very clear. It was then possible to follow the attrition process for any engagement. The attrition process functions exactly as programmed in the code.

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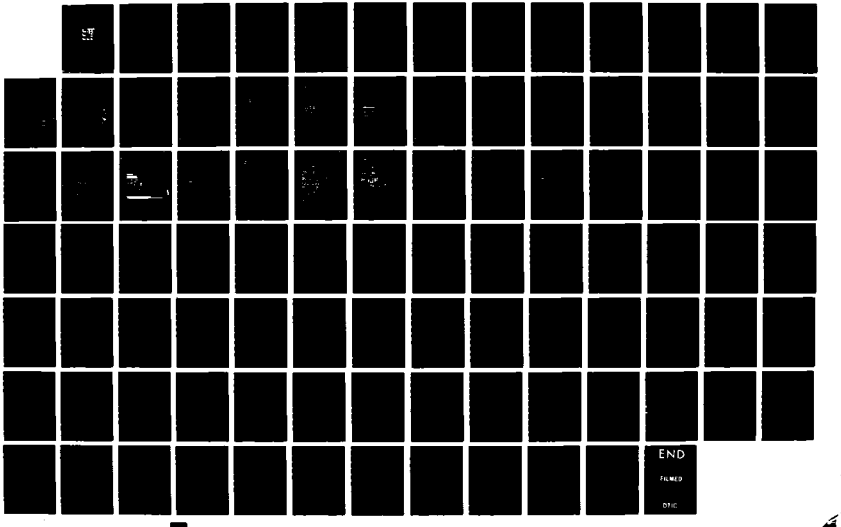

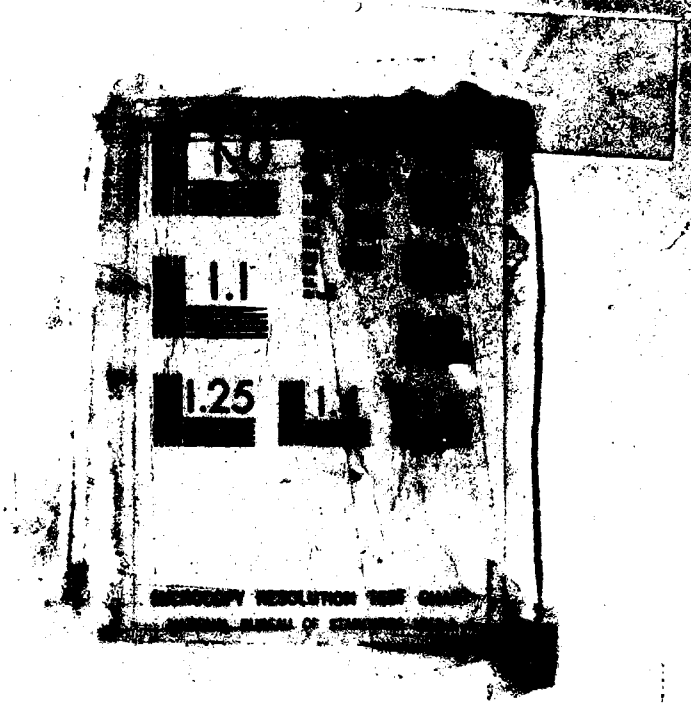
1.1
1.25

IV. THE MTM ATTRITION PROCESS.

It is necessary to understand how the MTM attrition process works to understand how the input parameters affect combat. All units are assigned a combat power value in the database. During combat this power is multiplied by values assigned to each input parameter. The attrition rate is generated using a simple homogeneous Lanchester type difference equation. This equation is:

$$\frac{\text{Loss}}{2 \text{ hours}} = \frac{(1.-(\text{Friendly Points}-.03\ \text{Enemy Points}))}{\text{Friendly Points}} * 100$$

Where:
Points=Unit Strength * Modifying Factors
Loss= Fractional decrease in Unit Strength.
Modifying Factors= The cumulative effect of the input parameters.

The source code was analyzed to determine the effect of each input parameter on the attrition equation. The data from each battle run was used to confirm this prediction.

V. TEST RESULTS.

The effects of each parameter are explained in this section along with the effects of daylight, darkness and weather.

UNIT STRENGTH: This directly affects the attrition process through the variable points. This strength is multiplied by the modifying values of the other input parameters. The combat losses of a unit are reflected by a decrease in this strength. This is exactly as predicted in the program and user manuals.

UNIT TYPE: The only effect of this parameter is to

determine the actions that are feasible for a particular unit to perform such as air attack missions or indirect fire. It has no effect on ground combat. This is as predicted in the code and the user manuals.

ENGAGEMENT TYPE: Whether the attacking or defending unit is still moving toward its destination or has already arrived when it makes contact has a significant effect. Both test results and code analysis indicate that a moving unit suffers a 60 percent reduction in combat power for the first four hours of combat. This could be taken to represent the greater firepower that a unit that is able to deploy into a prepared attack formation would have over a unit that runs into the enemy while still in a march column type of formation. Four hours does, however, seem to be an excessive time period to penalize a moving unit. A unit should be able to recover from the initial shock of combat and deploy into an attack or defensive formation within two hours. The game designates the attacking side as the side with the shortest average time in position during each two hour period. This does not have any other effect on attrition (SEE FIGURE III).

TIME IN POSITION: The time that a unit has been in position is used to determine what type of defensive posture the unit is in. The posture significantly effects the units combat power. For Blue units: Meeting engagement= time in position less than three hours. Hasty defense= in position between three and 72 hours. Deliberate defense= in position greater than 72 hours or at game start.

For Red units:

Meeting engagement= time in position less than one hour.

Hasty defense= time in position between one and three hours.

Deliberate defense= in position greater than three hours or at game start.

The effects of each posture are:

Meeting engagement: Does not change combat power.

Hasty defense results in a 50 percent increase in combat power.

Deliberate Defense increases power by 200 percent.

Both the attacking and defending units are modified in this manner (SEE FIGURE IV). Neither the game manuals nor the program code offer an explaination for the different times to assume a given posture by red and blue units. There does not appear to be any reason that red units should have an advantage when assuming defensive postures. It is not clear whether this was an intentional difference or an error was made in the code.

AMMO AVAILABILITY: Any unit that completely exhausts its supply of ammunition during combat is immediately destroyed. This occurs even if both units are out of ammunition at the same time.

POL AVAILABILITY: Any unit that runs out of fuel in combat is assessed a 50 percent reduction in combat power.

MINES: Minefield attrition is assessed independently and concurrently with combat attrition. This is accomplished by a separate subroutine. Mines do not affect the ground combat attrition equation. The attrition from minefields is

in addition to combat attrition. This makes sense from a real life point of view. Being trapped in a minefield would make a unit more vulnerable to attrition if it remained stationary, while the minefield would damage or destroy some of the forces if they attempted to maneuver to reduce their vulnerability to enemy fire (SEE FIGURE V).

CHEMICAL/NUCLEAR CONTAMINATION: Units are not affected by contamination beyond the effects of the initial spray or blast. The users manual predicts that a unit will lose one percent of its power every hour that it is in a contaminated hex. This does not occur in actual play. The discrepancy exists because the nuclear and chemical attrition subroutines have not been coded in the version of MTM furnished to USMA.

TERRAIN: Each hex is assigned a value representing the type of terrain predominate within the hex. The method for assigning a value to a terrain type is not completely explained, however, more restrictive terrain such as forested areas and urban areas are assigned higher values than less restrictive terrain such as open areas. Negative terrain values cut combat power in half. Positive terrain values less than two do not change the combat power. Values between two and three double combat power while values of three or more triple it (SEE FIGURE VI). As mentioned before, the game does not discriminate between unit types in assessing terrain modifiers. Obviously different types of units are helped or hampered differently by a certain terrain type than other types of units. Urban terrain

triples the combat power of any type of unit. This may be try for an infantry unit, but few tankers would consider their units to be at an advantage in restricted towns and cities. In real combat, tankers would try to bypass urban areas but in the game it would be advantageous for tankers to move into urban areas to gain the advantage of the 3.0 multiplier. The terrain modifiers should be put into a matrix that indexes the multiplier by both terrain and unit types.

UNIT ORIENTATION: MTM does not distribute a unit's combat power within its hex. Orientation is not simulated in MTM.

DAY/NIGHT AND WEATHER: These parameters have no effect whatsoever on the combat process. No effect is coded and none is claimed in the users manual. These parameters have an effect in other subroutines which in turn may affect parameters that do have an effect in the combat subroutine. This is an obvious weakness of the model. It cannot be assumed that all units in the theater are equipped with Standard Target Acqusition and Night Observation (STANO) devices or that the STANO devices make a unit as effective as it is in clear daylight conditions. It is reasonable to expect that attrition rates would decrease at night or during foul weather. The troops are more lethargic, morale is often lower and targets are harder to acquire and track during the night and in foul weather.

Each unit's combat power is multiplied by each modifying factor to produce the friendly and enemy point values. These values are then inserted into the attrition

equation to determine the loss rate for each two hour period. After all of the units' losses have been calculated, they are subtracted from the units' strength ratings. The combat subroutine reduces the percent rating and the unit strength rating only. Another routine depletes the appropriate amount of expended supplies.

VI. SAMPLE ATTRITION CALCULATION.

The following combat situation illustrates how the attrition process works. In this situation a red tank unit with a strength rating of 4.0 attacks a blue armor unit with a strength of 6.0. The red unit is moving toward hex AW 33 when it makes contact with the blue unit in AW 35 and halts in hex AW 37. The red unit is in a hex with forested terrain (2.0 value). The blue unit has been in an open terrain hex (1.0 value) since the start of the game. Using this data, the attrition rates generated by the game can be reproduced. The terrain values correspond to a particular combat multiplier value. For the red unit in forested terrain this multiplier is 2.0. The blue unit is in a deliberate defensive posture since it has been in its position since the game's start. This multiplies its combat power by 3.0. The red unit has been in position for about one hour which places it in a hasty defensive posture with a multiplier of 1.5. Because the red unit has not reached its destination hex and it has been in its position less than four hours since it made contact with the blue unit, it will suffer a 60 percent penalty for moving. It will have a combat multiplier of .4.

After calculating all of the multiplying factors, the computer will calculate the points for each side. This is done by multiplying the unit strength by each of the multiplying factors. For the red unit this would be: 4.0 * 2.0 * 1.5 * .4 = 4.8. For the blue unit this would be: 6.0 * 1.0 * 3.0 = 18.0. In calculating the losses, these values would be substituted into the attrition equation. For the blue unit this would be:

(1.0-(18.0-(.03*4.8))/18.0)*100=.8%

For the red unit this would be:

(1.0-(4.8-(.03*18.0))/4.8)*100=11.3%

These results match the actual attrition rates generated by the game for the first two hour period. If more than one unit was involved, the game would sum all of the points for each side before calculating an aggregate attrition rate for each side. If either unit was out of POL its strength would be cut in half. Either unit would be eliminated if it was out of ammunition regardless of the status of the opposing unit.

VII. CONCLUSION.

The MTM combat subroutine performs exactly as it has been programmed. The major flaws in the attrition subroutine arise from the fact that it completely ignores the effects of weather or day/night conditions on ground combat. Another significant deficiency is the lack of any type of documentation available at USMA that states how the values used as unit strengths, terrain values, time in position modifiers and the .03 attrition rate coefficient

are determined. These values may have simply been pulled out of thin air and have absolutely no relevance to real world conditions. The MTM combat subroutine does, however, provide a workable system to simulate ground combat attrition.

Further research must be performed in two areas: how to modify the program to simulate the effects of daylight, darkness and weather and what are the appropriate values to uses as unit strengths and modifying coefficients. The MTM model could then be modified to provide a much more accurate simulation of ground combat attrition.

The MTM model in its current form is a useful tool to give students a feel for what it is like to command an integrated theater force in combat. Beyond this it is highly unsuitable because too many factors are ignored in the combat process and those that are addressed have not been documented to establish their reliability. If the MTM model is to be used as a tool to teach strategy or to test hypothetical scenarios for planning purposes, the model should be modified to include all factors that are believed to significantly effect ground combat and all of the values used in the program should be checked to insure that they represent the real world situation.

FIGURE-I. - ATTRITION TABLE

ATTRITION

Cause	Effect on Combat Strength	Effect on Supplies	Delay
COMBAT	$\frac{\text{Loss}}{2 \text{ hours}} = \left(1. - \frac{\text{(Friendly Points-.03 Enemy Points)}}{\text{Friendly Points}}\right) \times 100\%$		Movement Stopped
Entering Minefield	3% Loss	None	2 to 4 hours
Entering Nuclear Contaminated Area	1% every hour unit remains in contaminated area.	None	½ to 1½ hours
Entering Chemical or Biological Contaminated Area	1% every hour unit remains in contaminated area.	None	2 to 4 hours
Receiving Nuclear Attack	Varies with number of sorties or volleys and weapon type.	Varies with number of sorties or volleys and and weapon type.	0 hours
Receiving Chemical or Biological Attack	Varies with number of sorties or volleys and weapon type.	Varies with number of sorties or volleys and weapon type.	0 hours
1 Aircraft Sortie	Varies with aircraft type and target type.	Varies with aircraft type and target type.	15 minutes per unit sortie
1 Artillery Unit Volley	Varies with artillery or missile type generally 1% loss for a full-strength volley		15 minutes per unit sortie

FIGURE-II - TERRAIN EFFECTS

TERRAIN EFFECTS

Terrain Type	Trafficability Reduction	Combat Multiplier
OPEN	1.0	1.0
FOREST	2.0	2.0
URBAN	3.0	3.0
MOUNTAINOUS	5.0	3.0
GOOD HIGHWAY	0.33	1.0
POOR ROAD	0.50	1.0
BRIDGED RIVER	0.5	1.0
RIVER	2.0	1.0
ANTITANK DITCH	3.0	1.0
MINEFIELD	2 to 4-hour delay	0.5
NUCLEAR CONTAMINATION	½ to 1½-hour delay	0.5
CHEMICAL OR BIOLOGICAL CONTAMINATION	2 to 4-hour delay	0.5

NOTE: The effects listed above are those currently in the program. Other effects such as superhighways, dirt roads, narrow rivers, and wide rivers could be added.

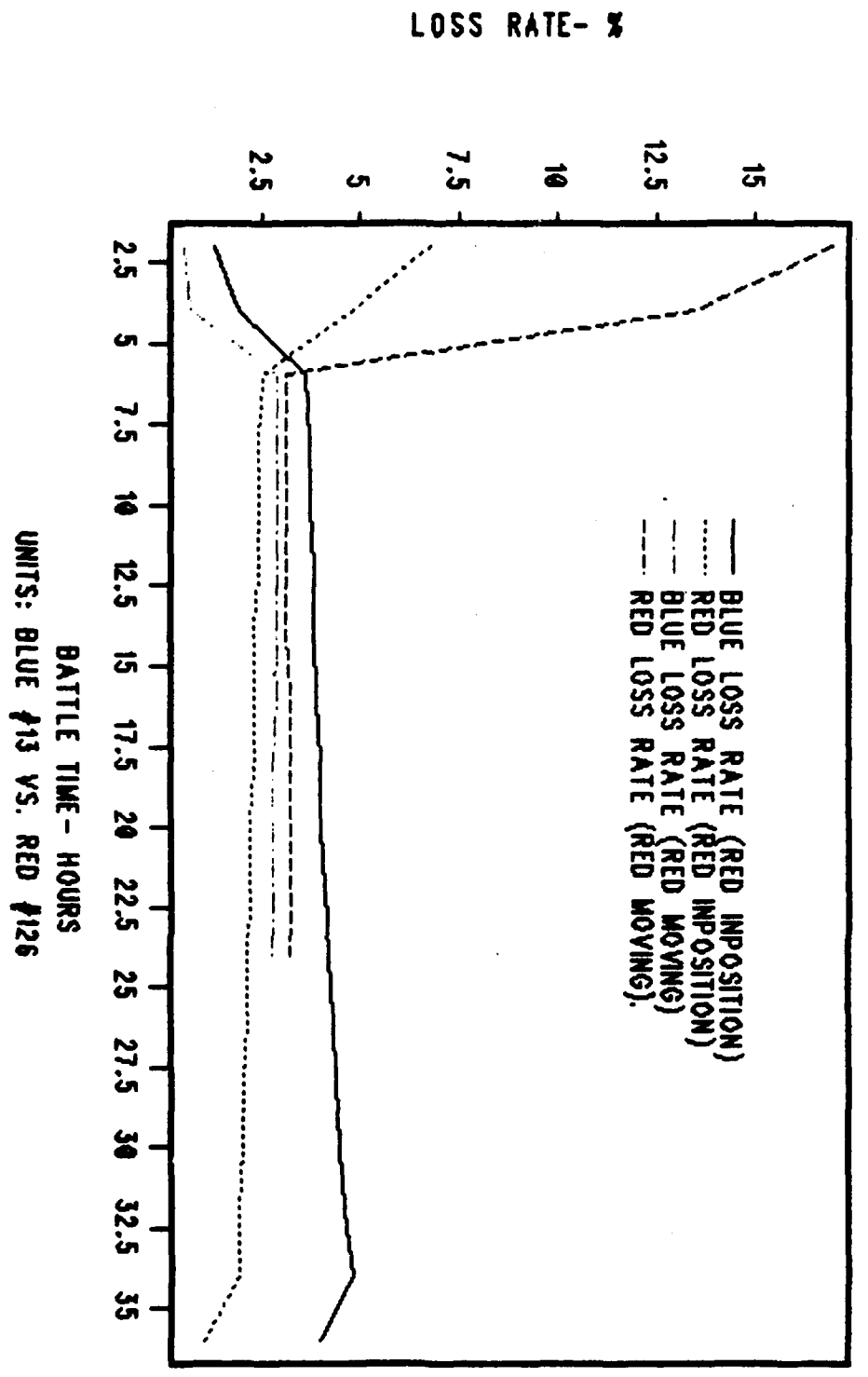
LOSS RATE- %
2.5
5
7.5
10
12.5
15
2.5 5 7.5 10 12.5 15 17.5 20 22.5 25 27.5 30 32.5 35
BATTLE TIME- HOURS
UNITS: BLUE #13 VS. RED #126
BLUE LOSS RATE (RED INPOSITION)
RED LOSS RATE (RED INPOSITION)
BLUE LOSS RATE (RED MOVING)
RED LOSS RATE (RED MOVING).
EFFECT OF POSTURE- MOVING V. INPOSITION

FIGURE-III

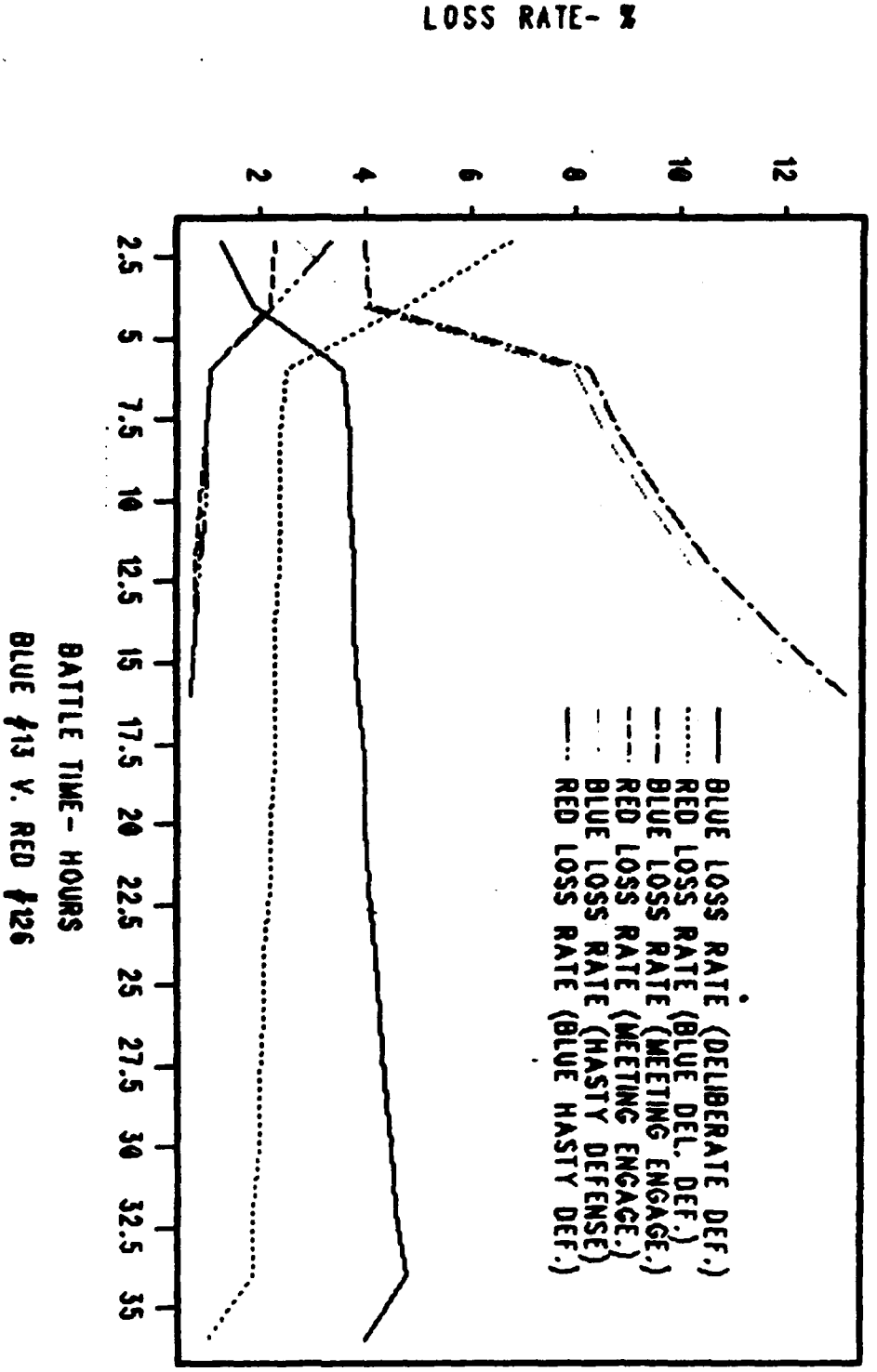
EFFECT OF ENGAGEMENT TYPE ON COMBAT
LOSS RATE- %
12
10
8
6
4
2
2.5 5 7.5 10 12.5 15 17.5 20 22.5 25 27.5 30 32.5 35
BATTLE TIME- HOURS
BLUE #13 V. RED #126
BLUE LOSS RATE (DELIBERATE DEF.)
RED LOSS RATE (BLUE DEL. DEF.)
BLUE LOSS RATE (MEETING ENGAGE.)
RED LOSS RATE (MEETING ENGAGE.)
BLUE LOSS RATE (HASTY DEFENSE)
RED LOSS RATE (BLUE HASTY DEF.)

FIGURE-IV

determine how much emphasis should be placed on the results. Certainly, a 2.62 percent attrition rate found in this run of FOURCE does not refute a 3 percent attrition rate used in MTM.

SUGGESTIONS FOR FURTHER RESEARCH

Although the 2.62 percent attrition rate found for blue forces in this run of FOURCE does not refute MTM's 3 percent rate, it also does not adequately justify its use. Further research can be performed on this subject by checking the attrition rates from other accepted models.

A determination of the red forces attrition rate in FOURCE, can be performed very easily. Using the steps provided in stage 2 of in the methodology of this report, this check can be performed within a reasonable amount of time.

Data provided by the Combined Arms Operations Research Activity located in Ft. Leavenworth,Ks.,is available here at the Academy. This data is on the Eur V warsame. Additional information needs to be requested before analysis on this data can be performed.

To any cadet who pursues further research in this area, I offer some sound advice based upon my own research experience:remember the first step to any problem in quantatative decisionmaking,THINK ABOUT THE PROBLEM. Before any information is extracted and manipulated from the large quantities of data available, be sure you fully understand

the attrition rate is an accurate representation of FOURCE's overall rate of attrition. The high standard deviation is an indicator of FOURCE's stochastic nature.

The FOURCE model is an accepted model by the modeling community. It "places particular emphasis on the simulation of staff performance and combat information/intelligence flow in order to measure the relative combat effectiveness of command and control and intelligence system alternatives."(Parish p.1-1) Although the main emphasis may not be on the representation of combat, this section of FOURCE's program does use valid inputs to determine losses. Thus, information extracted from its attrition outputs is valid.

The 2.62 percent gives evidence to support MTM's 3 percent attrition rate. The stochastic nature of FOURCE's attrition is not represented in MTM's combat subroutine. A new algorithm, which would fluctuate the attrition rate in MTM's combat subroutine, can be written,but this would not be practical. True, the attrition rate would fluctuate in a stochastic manner, but without valid inputs to decide when the rate would fluctuate, the subroutine would still not realistically represent actual combat.

SUMMARY

A check on the reasonableness of MTM's attrition rate has been performed. Depending on how much confidence a person has in this single run of the FOURCE model,will

3. The change in strength due to ground combat, from step 2, was divided by the starting strength of the division to obtain the fractional losses over the 30 minute interval.

4.MTM uses the equation

1.0-((BLUE-(.03)RED)/BLUE)*100=percent loss

to figure the percent loss per period.(BLUE,RED represent blue and red strengths) This equation can be transformed to isolate the .3 percent attrition rate. The resulting equation is

.03=(((percent /100)-1)BLUE+BLUE)/RED)

Percent loss divided by 100 is fractional loss. If we substitute this into the equation we then have all the data needed from our FOURCE output to find FOURCE,s attition rate over a 30 minute interval.

5.The resulting attrition rates need to be raised to the 4th power to convert the rate from a 30 minute interval to a 2 hour interval which is used by MTM.

RESULTS AND CONCLUSIONS

I performed a regression analysis on the attrition rate against time. An F-test on the results concluded that I could not reject the null hypothesis which states that the slope is equal to zero.(Annex E)This means the attrition rate is not really affected by the time. I found the mean of the attrition rate and found the attrition rate to be 2.62 percent with a standard deviation of 5.81 percent. The results of the F-test support my conclusion that the m an of

given at 30 minute intervals. Using the "summary of engagements" and the 30 minute output on "maneuver unit weapons and ammo," I was able to compile additional relevant data. Due to the stochastic nature of FOURCE, I no longer pursued the possibility of aggregating the attrition rate at battalion level to division level. I placed my emphasis on trying to determine the reasonableness of MTM's 3 percent attrition rate.

STAGE 2

Any time a battalion was in contact, the entire division was subsequently in contact. I tabulated the results starting from 60 minutes up to 1290 minutes, as the blue division represented in FOURCE, RUN 726, was in contact for the period from 45 minutes to 1289 minutes. I manipulated the data according to the following steps:

1.The overall starting strength of the blue division during the 30 minute interval was subtracted from the ending strength.

2.The change in strength, obtained in step 1, included losses due to air. MTM has a separate Air subroutine ;therefore, I only wanted results from FOURCE which reflected losses due to ground combat. From my FOURCE data, I added the losses due to air attack to the overall change in strength.

F distribution, there was significance in the regression between the attrition rate and time.(Annex A) The high standard deviation, the low correlation coefficients, and the plot of attrition vs. time (Annex C), caused me to pursue my investigation of the regression equation.

A plot of the standardized residuals showed 3 of the 40 data points, falling outside the (-2,+2) interval.(Annex B) These outliers were noted when I first regressed the data. In certain cases, outliers can and should be discarded to better fit a regression equation. In this particular case, the outlieing points are just as much a part of the model as any of the other output points. The occurance of the outliers informed me of the stochastic nature of the FOURCE model.

A regression of the attrition rate against time and minimum distance gave me a better model statistically, but I still observed outlieing points.(Annex D)

I began to manipulate my variables to regress a better fit line to the data. Even though I arrived at better models statistically, I disregarded these models and discontinued my pursuit in manipulating the input data. I was trying to force the data to fit the model. I was trying to "develop a statistical relationships among variables that were completely unrelated in the practical sense."(Hines p365-366)

Output on the number of weapons and ammunition remaining(the measure of strength in the FOURCE model) was

METHODOLOGY

The FOURCE data arrived in the form of 40 pounds of computer printouts. My strategy for attempting to obtain relevant results about attrition rates in FOURCE was to

FIRST, find the relevant data.
SECOND, extract and tabulate this data.
THIRD, manipulate this data so it corresponds with data output on attrition rates from MTM.
FOURTH, organize and describe the data from FOURCE.

STAGE 1

My initial intentions were to aggregate the battalion level attrition rates provided in the FOURCE output to attrition rates for a division level force, which could also be derived from the FOURCE output data. This meant I had to first work with the output of battalion engagements. A summary of each battalion's engagements for the blue force was given at the end of RUN 726's CAA printout. I organized this data in terms of percent strength attrited, time in contact, and minimum distance between units in conflict. I first regressed the attrition rate against time. Surprisingly, at a 95 percent level of confidence, using the

other validation work on MTM and gave me a general understanding of the model. Modeling and Simulation of Land Combat, explained the concept of using historical data to predict future events. More importantly, this book informed me of the relation between casualty rates and the size of the force in combat.

Force on Force Attrition Modeling gave me an excellent overview of when and how Lanchester equations can be used. The used of the Lanchester equation in MTM is very basic and this book went further in depth than was necessary for my research. I still found this work very worthwhile, as it simplified my understanding during the study of analytic techniques in ER466(Operations Research II). Lanchester Models of Warfare showed me the extensive applications of Lanchester equations.

Numbers, Predictions and War familiarized me with another technique of combat modeling. The extensive use of historical data and the use of an "operational lethality index" were quite interesting. The many variables, some non-quantifiable, that effect attrition were addressed in this work. After reading this book, I became fully aware that I should try to avoid trying to force a model to fit the data. Conversely, I wanted to avoid trying to force the data to fit the model.

"Modeling Command, Control, and Communications" and "Table 1. U.S. FOURCE Reader's Guide" became my Bible in terms of understanding the FOURCE model and data.

unit models to input for large unit models have been unsuccessful.

At the beginning of my research, it was my intent to see if the attrition rates in smaller units could somehow be aggregated to fit the attrition rates of larger size units. MTM is a theater level model which attrites division size units. By looking at small unit models such as FOURCE, I intended to try and aggregate the battalion level attrition to division level.

PROBLEM DEFINITION

Determine the attrition coefficient for the combat subroutine of the McClintic Theater Model.

PROBLEM OBJECTIVE

After analyzing data from already accepted combat models, I will .....1)be able to determine the reasonableness of MTM's attrition coefficients.....2)be able to determine a new coefficient of attrition.

REVIEW OF LITERATURE

The majority of the reading, which I have done for my research, was completed during the first part of the semester. Much of the reading was background reading on MTM and combat modeling.

"Combat Modeling Evaluation at USMA" and "A Detailed Analysis of the McClintic Theater Model" acquainted me with

INTRODUCTION

As interest in the use of the McClintic Theater Model grows, so does the interest in validating the model and its database. The United States Military Academy is the prime source for efforts directed toward the validation of the model. Faculty, as well as cadets, take part in the validation work. For my ER489 individual research project, I have chosen to work on the validation of one phase of MTM.

During my research, I have directed my efforts toward understanding attrition in MTM, as well as in other combat models. Most small unit models use hit probability and kill probability matrices, as well as tactical environment and weapons range considerations when determining how much a unit has been attrited over a given lenghth of time. These attrition determining factors are based upon facts and data which have been gathered from weapons tests, tactics manuals, and actual field experiments. These models generally have high resolution and are accepted by the modeling community because of their reliable input.

If the matrices and other inputs of the small unit level models were to be used in larger army or theater size models, the program for the larger model would be extremely lengthy and would take considerable time to run. Beside the fact that this information would place a high demand upon the computer, it is almost impossible to determine how these inputs would change as the size and diversity of the units in contact increased. Attempts to aggregate input for small

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ABSTRACT

The model validation program of the McClintic Theater Model at USMA was initiated upon the request of the Commandant, U.S. Army War College. This research paper investigates the validation of one phase of MTM. The 3 percent attrition rate in MTM's combat subroutine has been questioned by most combat modelers familiar with MTM. By evaluating the attrition rates in accepted combat models, a check on the 3 percent attrition rate in MTM can be performed.

Attempts were made to aggregate battalion level attrition to division level, but because of the stochastic nature of attrition at the battalion level, this aggregation was no longer pursued. Research continued with the emphasis being placed on determining the reasonableness of MTM's attrition rate.

The attrition rate found in the accepted FOURCE model was 2.62 percent. This 2.62 percent attrition rate provides evidence to support MTM's rate of 3 percent, although it does not provide a full justification. Continued research on this subject is necessary to fully justify the use of MTM's attrition rate. The results of this research report do provide a confidence statement for the use of the 3 percent rate.

REPORT ON THE ATTRITION RATE COEFFICIENT IN THE McCLINTIC THEATER MODEL

ER489 INDIVIDUAL ENGINEERING RESEARCH PROJECT REPORT

By CADET KEVIN F. MILES

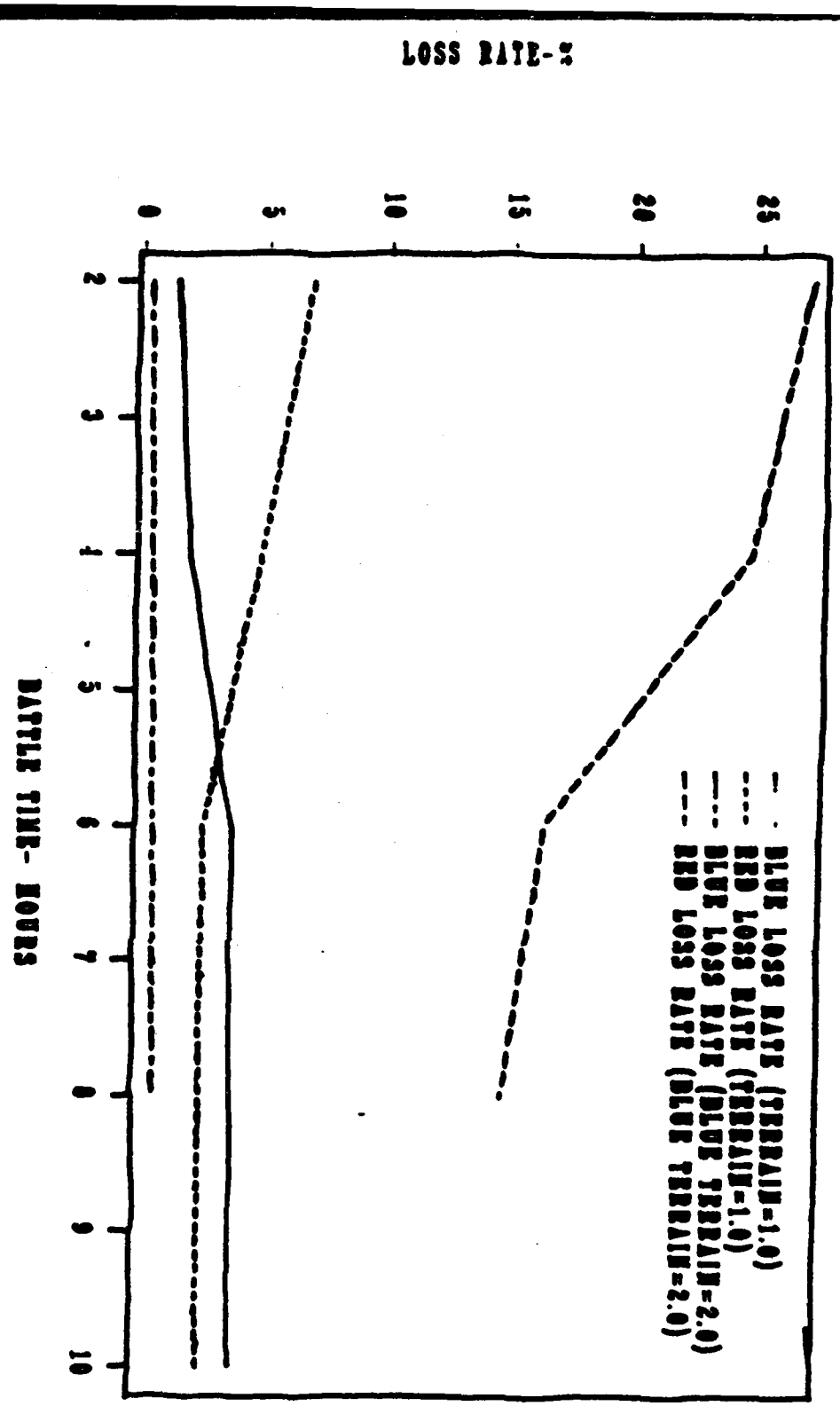
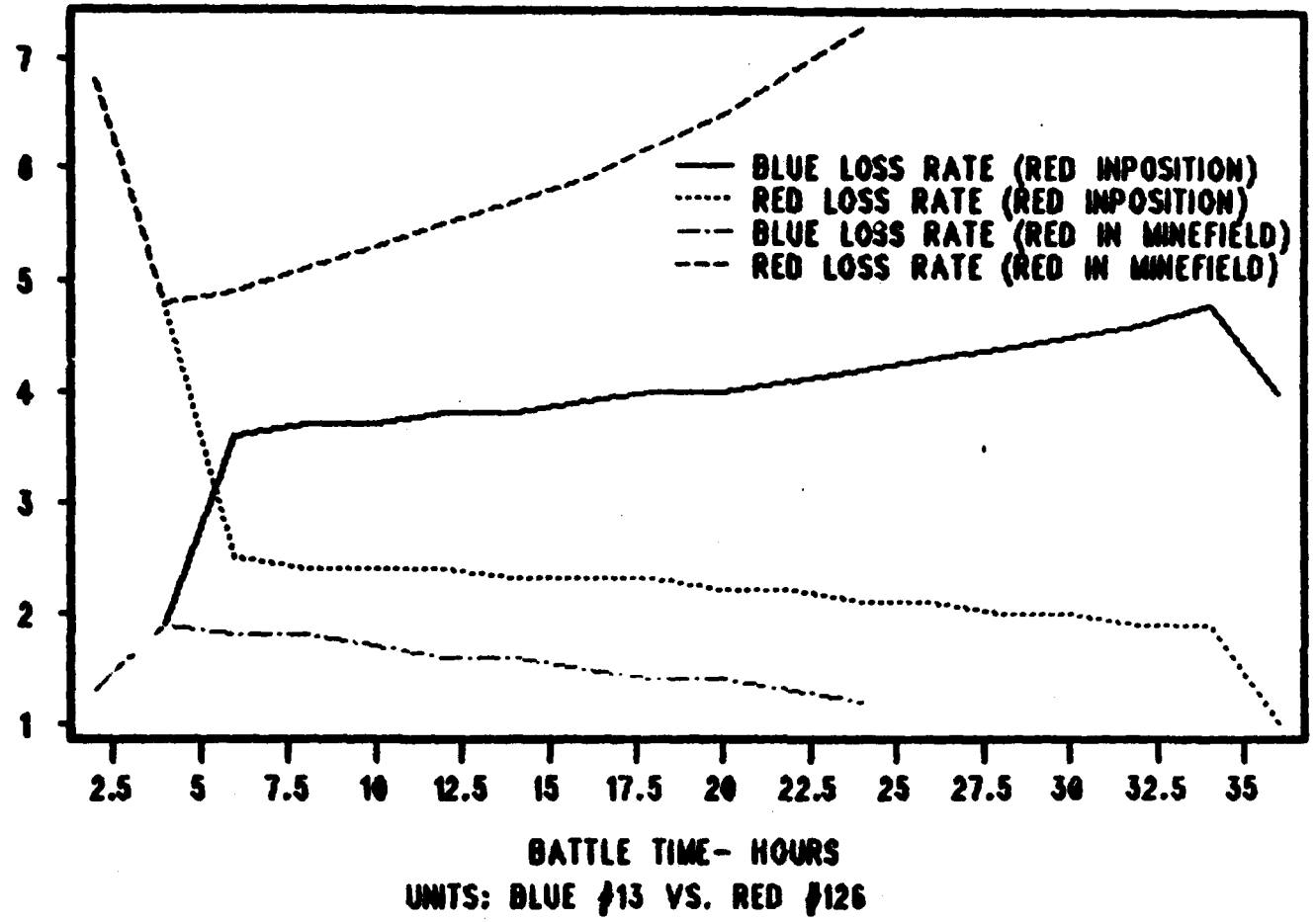

LOSS RATE-%
0
5
10
15
20
25
2
3
4
5
6
7
8
9
10
BATTLE TIME- HOURS
BLUE LOSS RATE (TERRAIN=1.0)
RED LOSS RATE (TERRAIN=1.0)
BLUE LOSS RATE (BLUE TERRAIN=2.0)
RED LOSS RATE (BLUE TERRAIN=2.0)
EFFECT OF TERRAIN ON COMBAT

FIGURE--VI

EFFECT OF MINEFIELD ON COMBAT



UNITS: BLUE #13 VS. RED #126

FIGURE-V

why you need the data. The operations to be performed on the data are relatively simple,but the time wasted performing these operations can be enormous if a logical approach is not taken.

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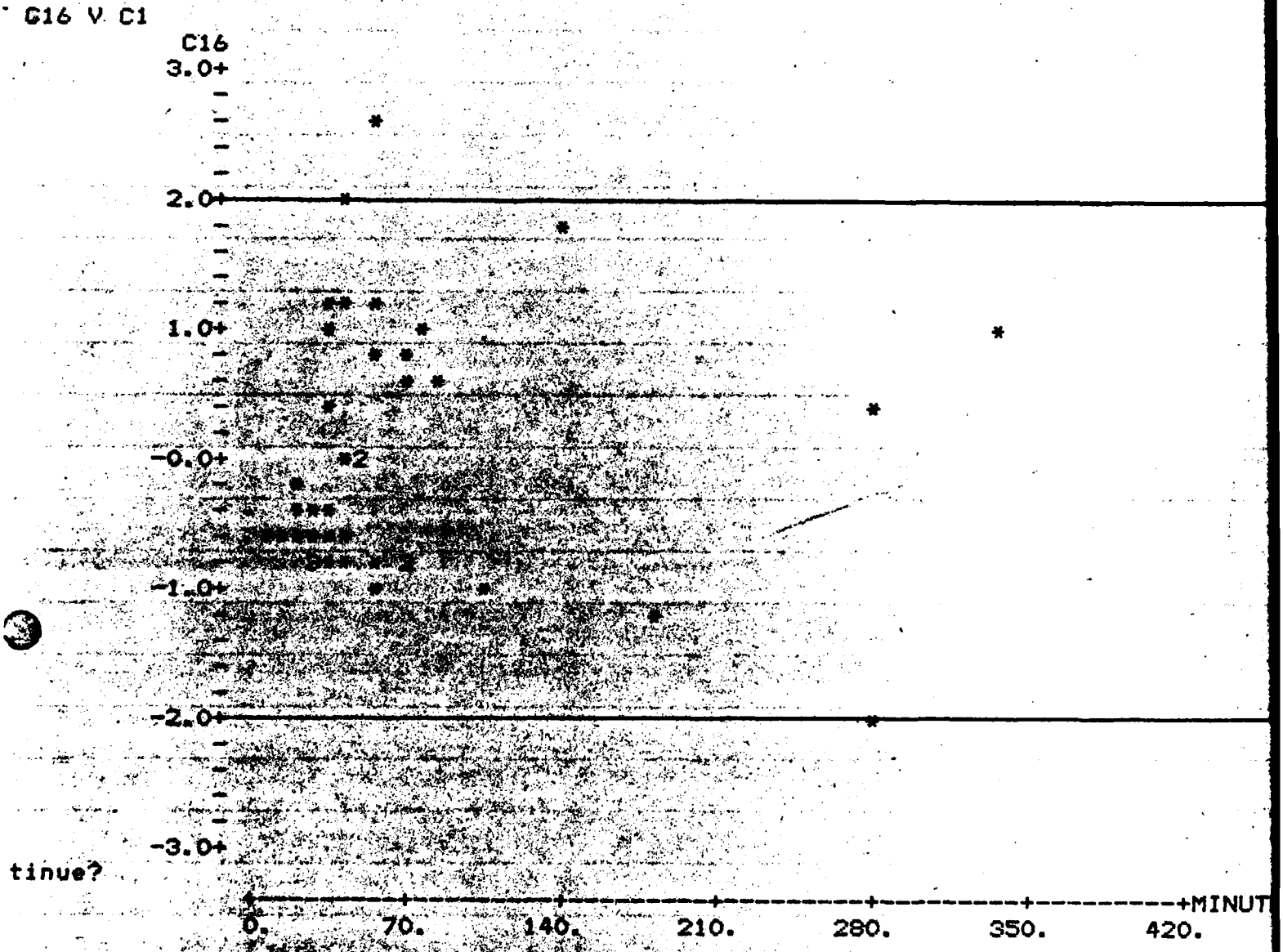
Miles KF
Annex A

A regression of time and Losses

```
REGRESS C3 1 C1 C16 C17 C18

THE REGRESSION EQUATION IS
LOSSES = 14.9 + 0.172 MINUTES

                                    ST. DEV.      T-RATIO =
COLUMN        COEFFICIENT           OF COEF.      COEF/S.D.
CONSTANT          14.867              5.403           2.75
MINUTES          0.17198            0.05351           3.21

[redacted]

[redacted] PERCENT
[redacted] PERCENT. ADJUSTED FOR D.F.

ANALYSIS OF VARIANCE

DUE TO          DF          SS          MS=SS/DF
REGRESSION       1      6397.9            6397.9
RESIDUAL        38     23531.5             619.2
TOTAL           39     29929.4

Continuation

                                PRED. Y   ST.DEV.
ROW   MINUTES      LOSSES        VALUE    PRED. Y    RESIDUAL     ST.RES.
  3        99       72.55        21.57       4.25       50.98       2.08[redacted]
  4        93       88.23        24.33       4.01       63.90       2.60[redacted]
 17       385       92.50        72.48      14.76       20.02       1.00[redacted]
 21       281       70.27        63.19      12.00        7.08       0.32[redacted]
 24       281       17.72        63.19      12.00      -45.47      -2.09R[redacted]

[redacted]

DURBIN-WATSON STATISTIC = 1.58

MTB >
```

Miles KF
ANNEX B

A Plot of the residuals from the regression equation "Losses = 14.9 + .172 Minutes"

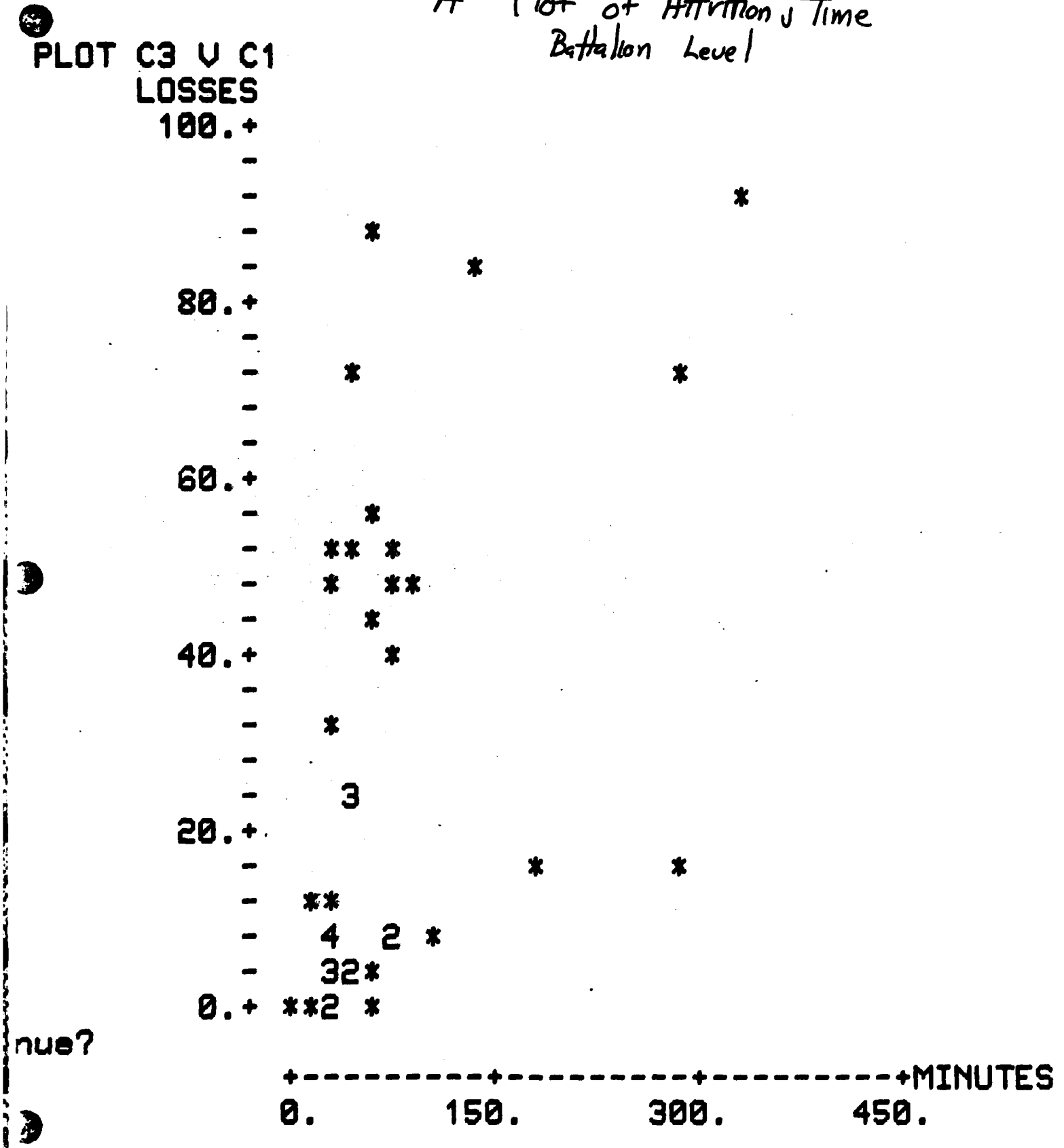


tinue?

>

Miles KF
Annex C

A Plot of Attrition v Time
Battalion Level



nue?

Miles KF
Annex D

Regression of Losses v Time, Min Distance

```
REGRESS C3 2 C1 C4 C90 C91

THE REGRESSION EQUATION IS
LOSSES = 85.5 + 0.185 MINUTES - 0.0372 MIN.DIST

                                    ST. DEV.     T-RATIO =
COLUMN       COEFFICIENT          OF COEF.     COEF/S.D.
                   85.49              10.27          8.33
MINUTES          0.18508            0.03471          5.33
MIN.DIST       -0.037154           0.005079         -7.32

S = 16.12

R-SQUARED = 67.9 PERCENT
R-SQUARED = 66.1 PERCENT, ADJUSTED FOR D.F.

ANALYSIS OF VARIANCE

 DUE TO      DF          SS          MS=SS/DF
REGRESSION    2       20310             10155
RESIDUAL     37        9619               260
TOTAL        39       29929

Continue?
FURTHER ANALYSIS OF VARIANCE
SS EXPLAINED BY EACH VARIABLE WHEN ENTERED IN THE ORDER GIVEN
 DUE TO      DF          SS
REGRESSION    2       20310
MINUTES       1        6398
MIN.DIST      1       13913

                          Y      PRED. Y    ST.DEV.
 ROW  MINUTES      LOSSES      VALUE    PRED. Y   RESIDUAL    ST.RES.
   4       55       88.23      48.67       4.22      39.56     2.54R
  17      335       92.50      82.62       9.66       9.88     0.77 X
  18        5        0.00      35.07       4.29     -35.07    -2.26R
  21      281       70.27      73.15       7.89      -2.88    -0.20 X
  24      281       17.72      38.37       8.48     -20.65    -1.51 X

R DENOTES AN OBS. WITH A LARGE ST. RES.
X DENOTES AN OBS. WHOSE X VALUE GIVES IT LARGE INFLUENCE.

DURBIN-WATSON STATISTIC = 1.77

MTB >
```

Miles KF
Annex E

Attrition Rate in Fource v. Time

```
THE REGRESSION EQUATION IS
2HR-RATE = 0.0289 - 0.00026 INT-TIME

    38 CASES USED     3 CASES CONTAIN MISSING VALUES

                                ST. DEV.     T-RATIO =
COLUMN      COEFFICIENT         OF COEF.     COEF/S.D.
                0.02887          0.01934          1.49
INT-TIME     -0.000258         0.001612         -0.16

S = 0.05887

R-SQUARED =  0.1 PERCENT
R-SQUARED =  0.0 PERCENT, ADJUSTED FOR D.F.

ANALYSIS OF VARIANCE

 DUE TO      DF          SS          MS=SS/DF
REGRESSION    1     0.000089          0.000089
RESIDUAL     36     0.124785          0.003466
TOTAL        37     0.124874

Continue?

                                    Y    PRED. Y    ST.DEV.
 ROW  INT-TIME   2HR-RATE          VALUE   PRED. Y  RESIDUAL      ST.RES.
  28     14.0    0.34962         0.02527   0.01115   0.32436       5.61R

R DENOTES AN OBS. WITH A LARGE ST. RES.

DURBIN-WATSON STATISTIC = 2.01

MTB >
```

Miles KF.
Annex F-1

PRINT C20 C24

ROW	TIME	TOTALSTR
1	0.0	827.4
2	0.5	797.3
3	1.0	738.2
4	1.5	685.8
5	2.0	666.6
6	2.5	659.5
7	3.0	653.7
8	3.5	715.1
9	4.0	709.1
10	4.5	708.8
11	5.0	708.8
12	5.5	704.3
13	6.0	697.0
14	6.5	677.7
15	7.0	674.6
16	7.5	670.7
17	8.0	664.6
18	8.5	644.3
19	9.0	639.7
20	9.5	615.8
21	10.0	609.2

Continue?

Miles K.F
Annex F-2

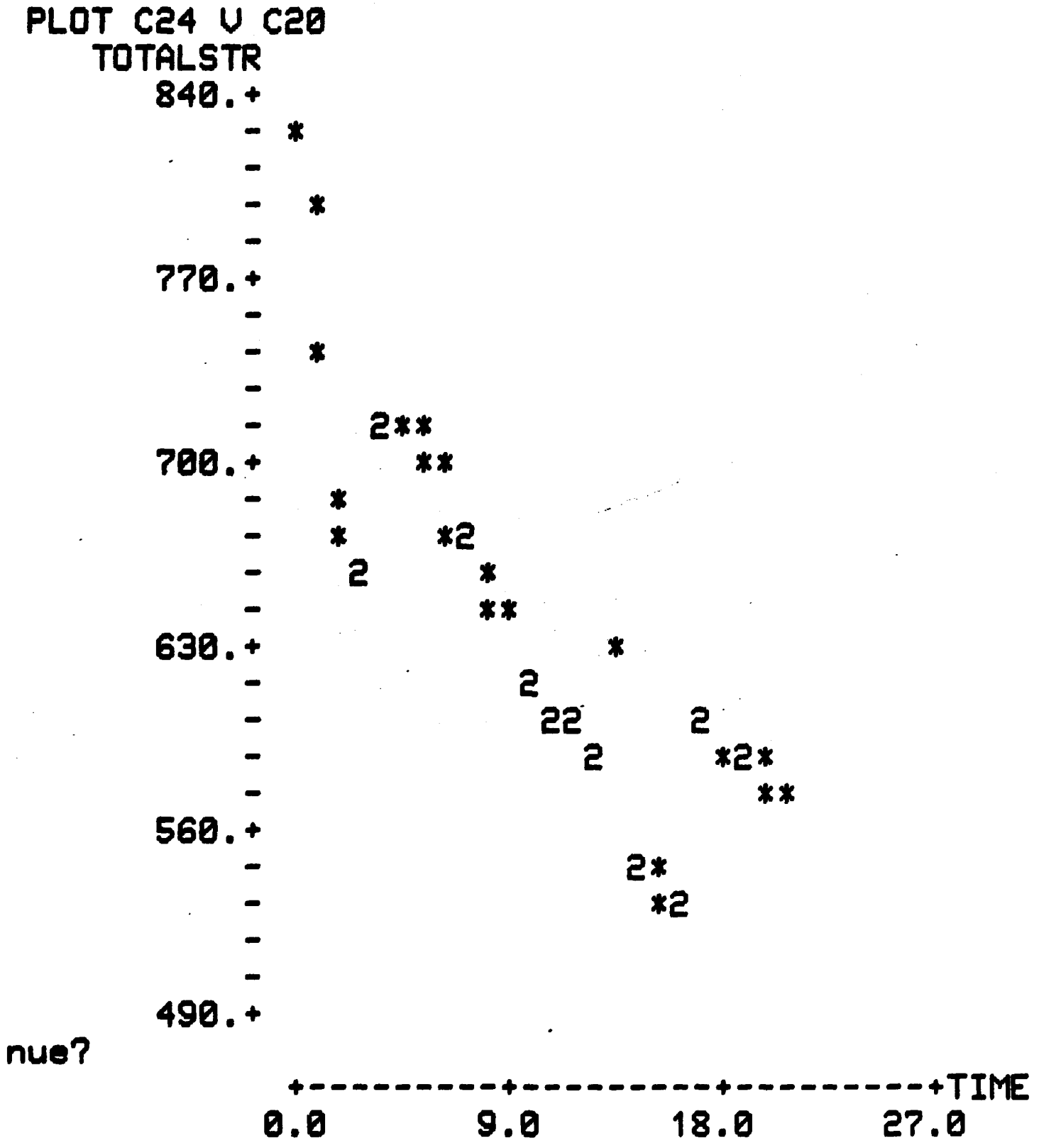
17	8.0	664.6
18	8.5	644.3
19	9.0	639.7
20	9.5	615.8
21	10.0	609.2

Continue?

22	10.5	604.2
23	11.0	601.0
24	11.5	599.7
25	12.0	595.8
26	12.5	591.5
27	13.0	589.2
28	13.5	633.5
29	14.0	550.1
30	14.5	542.7
31	15.0	542.6
32	15.5	536.6
33	16.0	536.2
34	16.5	529.6
35	17.0	600.1
36	17.5	595.7
37	18.0	592.7
38	18.5	588.5
39	19.0	584.4
40	19.5	582.6
41	20.0	580.9
42	20.5	579.9

MTB >
MTB >

Miles KF
Annex G



MilesKF
Annex H

Description of FOURCE's Attrition Rate

```
DESCRIBE C68

            2HR-RATE
N                 38
MEAN          0.0262
MEDIAN        0.0098
TMEAN         0.0161
STDEV         0.0581
SEMEAN        0.0094
MAX           0.3496
MIN           0.0000
Q3            0.0202
Q1            0.0042
MTB >
```

Analysis of Movement In The

McClintic Theatre Model

By Thomas A. Dufresne

Acknowledgements: I acknowledge the assistance of LTC Bettencourt in coming up with the topic of this research. LTC Bettencourt provided me with access to the model and reccomended the methodology to be used in my research. Mr. Mark Adams of the concepts analysis agency provided me with the information in tables 3,4 and 5. ~~This~~ He also provided me an explanation of how the movement algorithm worked and CAA's analysis of the algoritm. His explanation of the algorithm was in agreement with what I had alresdy determined the algorithm to be. The data in tables 3,4 and 5 is easily verified by looking in the file WAR-DATA and in the appropriate subroutines in MTM. Cadet John Morris provided assistance in accessing MTM and in getting it to run.

Thomas A Dufresne

he McClintic Theater Model is an interactive computer simulation of heater level warfare, designed for the education of senior level fficers in the operations, strategy and problems of conducting war at he theater level. From the model, the student can learn the effects f various methods of troop employment and the logistical complications resent in any large scale conflict.

n order that the educator and the student feel confident that the ight lessons are being learned, they have to feel confident that the odel is an accurate representation of theater level warfare. One of he primary principles of war as expressed by current Army doctrine, in M-100, is Manuever. A commander must "place the enemy in a position f disadvantage through the flexible application of combet power". The ositioning of troops on the battlefield has always been of critical oncern to the commander. Any model that attempts to model warfare ust therefore concern itself with the movement of combat and combat upport units. If the model is to accurately simulate war, it must ccurately simulate force movement.

he purpose of this paper is to determine how MTM models ground ovement and determine how reasonable this model of movement is ompared to the actual movement of ground units. Finally, the pplicability of this movement model, in a simulation designed for ducating senior level officers, will be addressed.

ere are two parts to any movement movement routine in a war mulation. These two parts are the mechanics of movent and the rate movement. If the model is to model movement adequately, it must equately model movement rate and movement mechanics.

vement Rates in MTM

ere are many factors which effect the rate at which ground units ve. Some of the most significant of these are listed in Table 1. M models each of these factors, if at all, in a number of different ys. If the adequacy of MTM's movement rates is to be determined, en it will be necessary to determine how adequately MTM adresses each these factors.

round Slope

e general effect of ground slope on the speed at which a unit moves fairly obvious. If the unit is moving uphill then its speed will be ss than what it could be if it were moving on flat ground. MTM does t take ground slope into account. If MTM were going to account for lope it would have to have some idea of the elevations in each hex. M does not store such data.

it Size/Efficiency

:urately model theater level warfare. The McClintic Theater Model)uld be used at West Point as a training aid in teaching cadets about ıbat simulation and wargaming. Future work on MTM at West Point)uld be along the lines of cadets developing their own algorithms for ; many subroutines in the model. Additionaly, work should be done on veloping a methodology for arriving at and properly documenting all ıerical constants to be used in any algorithm. MTM in the form in ıch it currently exists at West Point should not be used by the Army : College to teach senior level officers about theater level warfare.

Weather

Unit size

Unit type

Engineer Assets

Ground Slope

Vehicle Reliability

Further more, the values used to model the effects of all other factors are not reliable and appear to be arbitrary.

The model does not allow troops to be transported by railroad.

The movement algorithm looks only one hex away when determining the path of a moving unit. This produces a route of movement which is often meandering and not in agreement with the route a commander would have the unit follow. The route taken in no way follows what would be the easiest route. It ignores all information about enemy location which makes it possible for the unit to run into the enemy, even when the commander knows the enemy location and wishes to bypass it.

:ommendations:

t needs extensive revision before even the movement subroutines

fter all orders have been read, the program control is eventually ransfered to MANEUV. It is in MANEUV where the unit is actually oved. MANUEV cycles through all the units in the data base and checks o see if they are ready to be moved. If they are ready and they have uel, their location is changed to that of their next hex. If they are t their destination, their status is set to availible. After the unit s moved, checks are made to determine if the unit left or entered a ity hex or entered a mined or contaminated hex. If either of these onditions exists then appropriate actions are taken and delays ssesed. The subroutine then determines if the unit has moved adjacent o an enemy unit. If it has moved adjacent to an enemy hex, the unit's tatus is set to combat. The next hex a unit will move into is letermined in subroutine MOVNXT. In MOVNXT, the distances from the six exes adjacent to the moving unit, to the unit's destination are letermined. The model then determines the time it would take the unit o move into each of these six hexes. The direction which would result n the greatest reduction of distance to the destination per unit time s the direction of the unit's next move.

eficiences

her are a number of places where this model fails to adequately epresent reality. Some of thes are as follows:

The model ignores or fails to accurately model the effects of the folowlowing factors on movement:

Method of Movement in MTM

MTM uses a relatively simple algorithm to move units. Location in MTM is given in terms of hex coridintes. When a commander desires to move a unit, he inputs a move order. The essential elements of a move order in MTM are the key word 'move', the unit to be moved, and the unit's destination hex.

Other information may be added to the order but it is not required. The optional data in a move order are the speed the commander desires the unit to travel at and the time he wants them to start moving. If the movement speed and start time are not given, the model sets the movement speed to the units maximum speed and the start time to the time the order was recieved. There are three major suroutines in MTM which handle unit movement. These subroutines are MOVORDER, MOVNXT and MANEUV. The flow chart for the overall logic of movement in MTM is given in appendix 1.a. Flowcharts for the major movement subroutines are in appendix 1b.-1d. In general, the movement logic works as follows. The commander inputs a movement order. This order is determined by the key word move to be a movement order and control of the program transfers to MOVORD. In MOVORD the model determines if the order is a valid movement order. If it is valid, the subroutine creates a dummy location for the unit being moved and moves it to its destination ignoring battle conditions in order to determine an estimated arrival time, which it transmitted to the commander. MOVORD calls MOVNXT to determine the first hex the moving unit will be moving into and calculates the time the unit will arrive in the next hex.

fourth.

Desires of The Commander

If a commander wishes to push his men to their fullest capability, he can do it. It will however have an effect on morale and safety. If a commander wants to get from point A to point B as fast as possible he will have to pay the price. On the other hand, if their is no urgency, a commander can move at a steady orderly pace and make it to his destination with troops that are mentally and phisically prepared to fight. MTM allows a player to set the speed for a unit and it will move the unit at that speed so long as it does not exceed the maximum speed adjusted for terrain , barriers, day or night effects and weather. MTM does not penalize a unit that moves at its maximum speed.

Maximum Speed

It is evident from the above analysis that the movement rates in MTM are very dependent on the values assigned for maximum speeds and the variuos modifying factors. Maximum speeds in the current West Point Nato data base range from 6 to 10 MPH. There is no documentation available showing how these values or the modifying factors were arrived at.

Note that the terrain code used is that of the hex being entered.

Weather

Weather can have a number of substantial effects on a unit. It can effect morale, vehicle reliability, trafficability and visibility all of which can cause changes in a unit's movement rate. In addition, it is not only the current weather wich will effect movement. The weather for the past few days or weeks may have made significant changes to the trafficabilty of the soil which would not be expected if only the current weather were observed. MTM models three types of weather; clear, rain, fog/snow. Temperature effects are not modeled. Neither are the effects of long periods of rain or snow. MTM models the effects of weather by modifying a units maximum speed by a weather factor. The weather factors are given in Table 5. To get a units new speed after adjusting for weather, MTM divides the units max speed by the weather factor.

Day/Night

The effects of day or night on a units movement rate are primarily caused by changes in visibility. Reduced visibility will have varying effects depending on the terrain and proximity to the enemy. MTM models the effects of night on a unit's speed by cutting it by a

MTM Barrier Codes and Factors

Code	Barrier Type	Traffic Factor
1	Open	1.0
2	River	3.0
3	Bridge,Tunnel,Poor road	.50
4	Road	.35
5	Road	.50
6	Undefined	-
7	Wadi	3.0
8	Ditch	3.0
9	Impassible	99999.

Table 3.

MTM Terrain Codes

Code	Terrain Type
1	Open
2	Forrest
3	Urban
4	Mountain
5	
6	Water

Table 4.

MTM Weather Factors

Weather	Factor
Clear	1.00
Rain	1.25
Fog/Snow	2.00

Table 5.

associated with the terrain type the unit is moving through. The exact time calculation will be discussed in the next section on the effects of terrain on movement.

Ground Trafficability

Different units are able to traverse different terrain types at different rates. Mechanized units move very well on well paved roads or hard soil, but they are severely hampered by things such as swamps, forests, mountains, cities, sand or mud. Leg Infantry, although also hampered by these terrain types, is not hampered to anywhere near the same extent. MTM does model the fact that different terrain types impede movement to different extents, but it does not model the fact that different unit types perform differently in the same terrain.

MTM currently models five terrain types. These terrain types and there associated codes are listed in Table 4. MTM uses the terrain code and the traffic factor between hexes to determine the time it will take a unit to move between the two hexes, given a units speed on open ground. The units speed on open ground is determined by the factors which will be discussed in the next few sections. The equation for calculating the time to move between two hexes is:

If there is a bridge or road between the two hexes

Travel Time = Hexsize/((Traffic Factor + .02)*Speed)

Otherwise

Travel Time = Hexsize/((Traffic Factor * Terrain Code + .02)*Speed)

Obstacles

Natural

- **River**
- **Swamp**
- **Ravine**
- **Dense Vegatation**
- **Wadi**

Man Made

- **Abatis**
- **Tank Ditch**
- **Barbed Wire**
- **Mine Field**

Table 2.

While moving from one location to another, a unit will encounter many obstacles. Some of the obsltacles will be manmade and others will be natural. In either case the unit's movement rate will be slowed down as the unit either clears the obstacle or goes around it. The ability of a unit to clear or breach an obstacle is a function of its engineer assets. MTM does not account for the differences in engineer assets between various units.

Natural/Enemy Obstacles

As has already been stated, MTM does not account for the differing ability of variuos types and size units to overcome obstacles. It does however model the fact that obstacles do exists and that they do slow down movement. Table 2 lists some of the possible obsticles that a unit could come up against. MTM has two different ways of modeling obstacles. One method is for mine fields and the other method is for all other types of obstacles. MTM models the effects of mine fields by adding a random time delay on to a unit entering a mined hex. Currently, the time delay for any unit entering a mined hex is a random number between two and four hours. MTM models all other obstacle effects by assigning each hexside a barrier code. MTM uses this code to record the existance of any natural or manmade features which would either impede or aid movement between hexes. The features currently modeled by MTM and there codes are listed in Table 3. Also listed in Table 3 is a traffic factor for each barrier type. The traffic factor is used to calculat the time it takes for a unit to move from one hex to another. Also involved in this calculation is a terrain factor

does not check for ports or airstrips at the units destination. MTM does not model rail transportation.

NBC Conditions

Under nuclear chemical or biological conditions a unit's movement will be slowed down by due to the fact that troops will be foced to don protective gear and mechanized units will travel buttoned up. Delay will aslo occur While units are being decontaminated. On the other hand, troops will have a tendancy to move as fast as they can through the contaminated area, even if this exceeds the movement rate set by the commander. MTM models NBC conditions by adding a random time delay on to a unit moving into a contaminated hex. For a nuclear hex the delay is a random number between .5 and 1.5 hours, and for a chemical or biologcal hex the delay is a random number between 2 and 4 hours. These delays are for hexes which are ten miles across.

Vehicle Velocity

There is no need to discuss the role vehicle velocity plays in determining movement rates. MTM accounts for vehicle velocities in the maximum speeds that it sets for each unit.

Engineer Assets

When a unit is on the move , vehicles will break down. When a vehicle breaks down, at a minimum, time will be lost as men and equiptment are transferred from the down vehicle to operational vehicles. If the breakdown occurs in relatively tight terrain, such as in a forrest or in the mountains, and it is difficult or impossible for other vehicles to go around the obstruction, then delay will be even greater. In the worst case, the failure has occured in a vehicle critical for the accomplishment of the mission. The unit must then wait for it to be repaired or for a replacement to arrive. The rate of vehicle failure increases with the amount of time the unit has been on the move. While a unit is moving, there is little time for proper PMCS. Even when there is sufficient time, the conditions may not be condusive to PMCS being done properly. As a result of insufficient maintainance, vehicles will break down with increased frequency. MTM does model vehicle failure. It does this by reducing a units strength every time it changes hexes. The unit's strength is reduced by .00005 percent at every hex. This amount does not increase with the amount of time the unit has been moving. MTM does not model the effect of vehicle failures on movement rate.

Mode Of Transportation

In warfare, a commander does not always have to move his unit to battle under its own power. He may instead put it on ships, trains or planes. MTM allows players to sealift and airlift units. It allows them to do this substantially more than would be the case in reality because it

I feel it would be reasonable to assume that as the size of a unit increases, its efficiency decreases. A squad leader has direct control over all of his men. When he makes a decision there is very little time lag before his men begin to carry it out. A platoon can only be as efficient as its best squad. In reality it will be even less efficient because there is delay between the platoon leader telling the platoon sargeant what he wants and the platoon sargeant telling the squad leaders. In addition platoon activities take more planning than those of a squad. More time lag is added when different subunits must coordinate with one another. This is especially the case when some tasks must be completed before others can even be begun. This inefficiency multiplies as the number of sub-units in an organization increases. Even at the same oganizational level, different units have different efficiencies. Part of these differences may be accounted for in the ability of the commander and his staff and some may be accounted for in the different organizations and missions of the various units. When given an order to move, there will be a time delay before a unit actually begins to move. This time delay is a function of the units efficiency. MTM does not take efficiency into account when it determines how quickly a unit responds to a movement order. A unit's size will also have a direct effect on movement rate because bottle necks on the route of advance will have a greater effect on large units than on small units. If MTM accounts for size and efficiency at all then it is in an aggregate manner in the values given for a units mximum speed. These values will be discussed later.

Vehicle Reliability

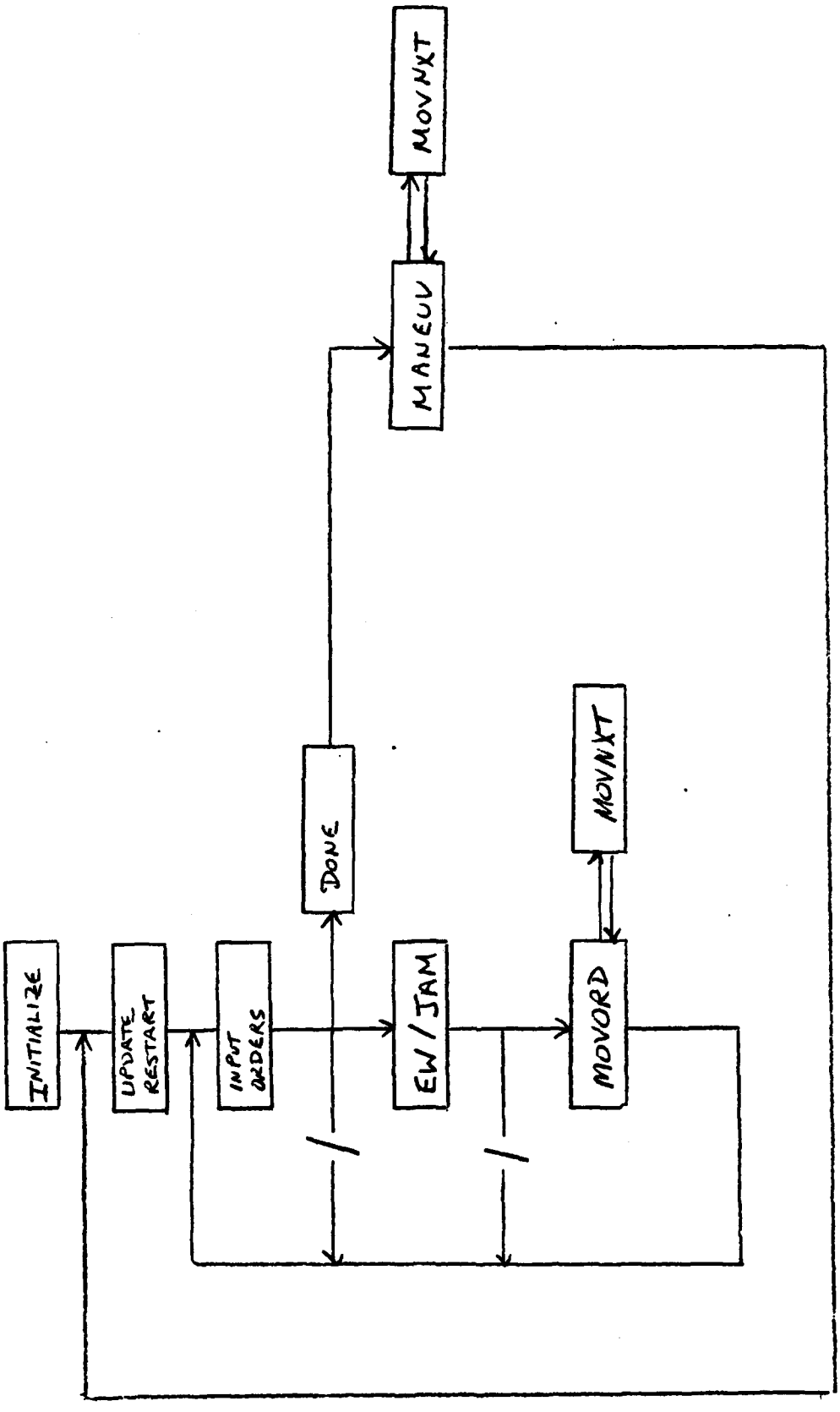
Factors Effecting Movement Rate

- Ground Slope
- Unit Size/Efficiency
- Vehicle Reliability
- Mode of Transportation
- NBC Conditions
- Vehicle Velocity
- Engineer Assets
- Natural/Enemy Obstacles
- Ground Trafficability
- Weather
- Day/Night
- Desires of Commander

Table 1.

OK,

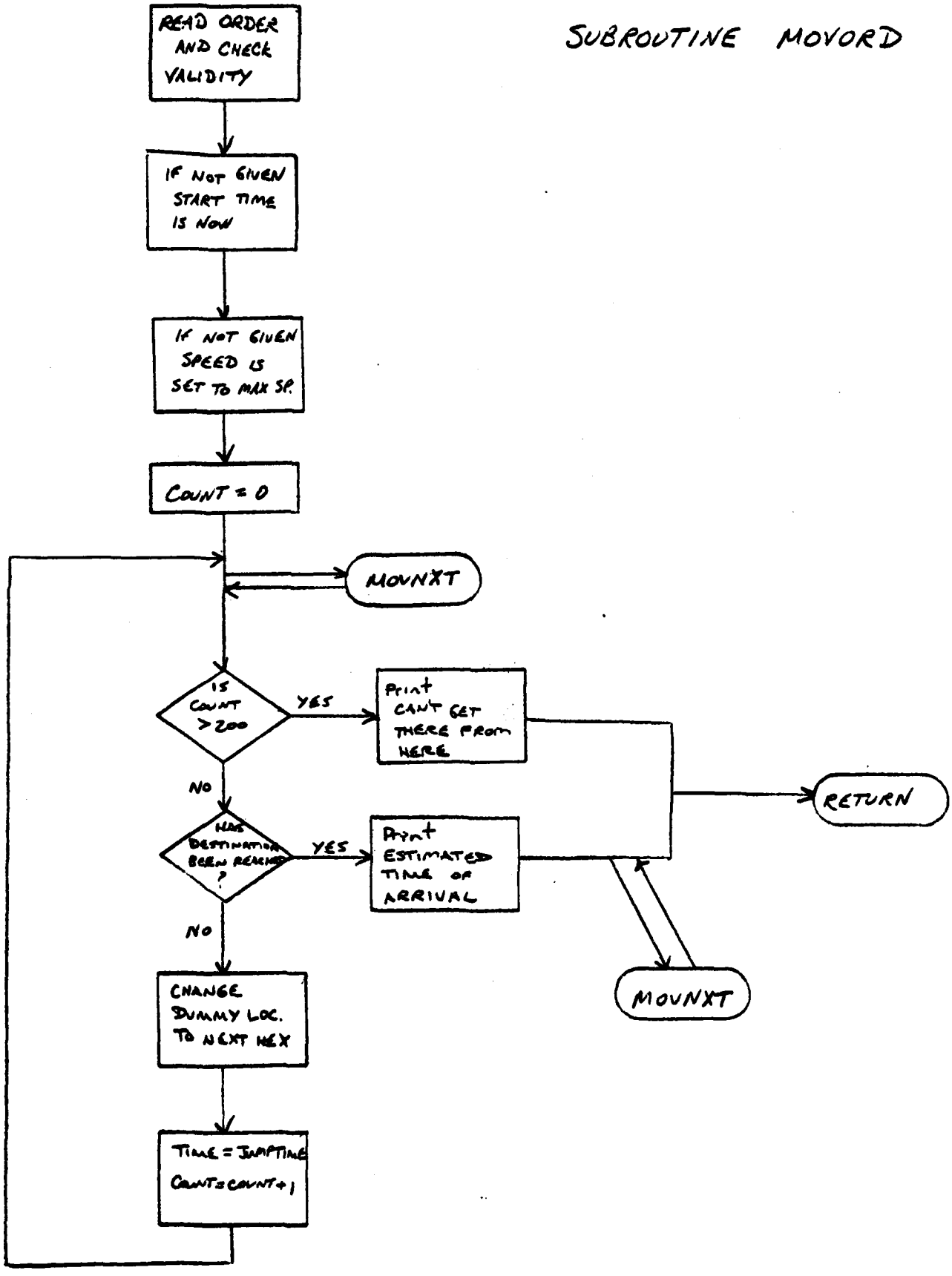
MTM MOVEMENT : OVERALL VIEW



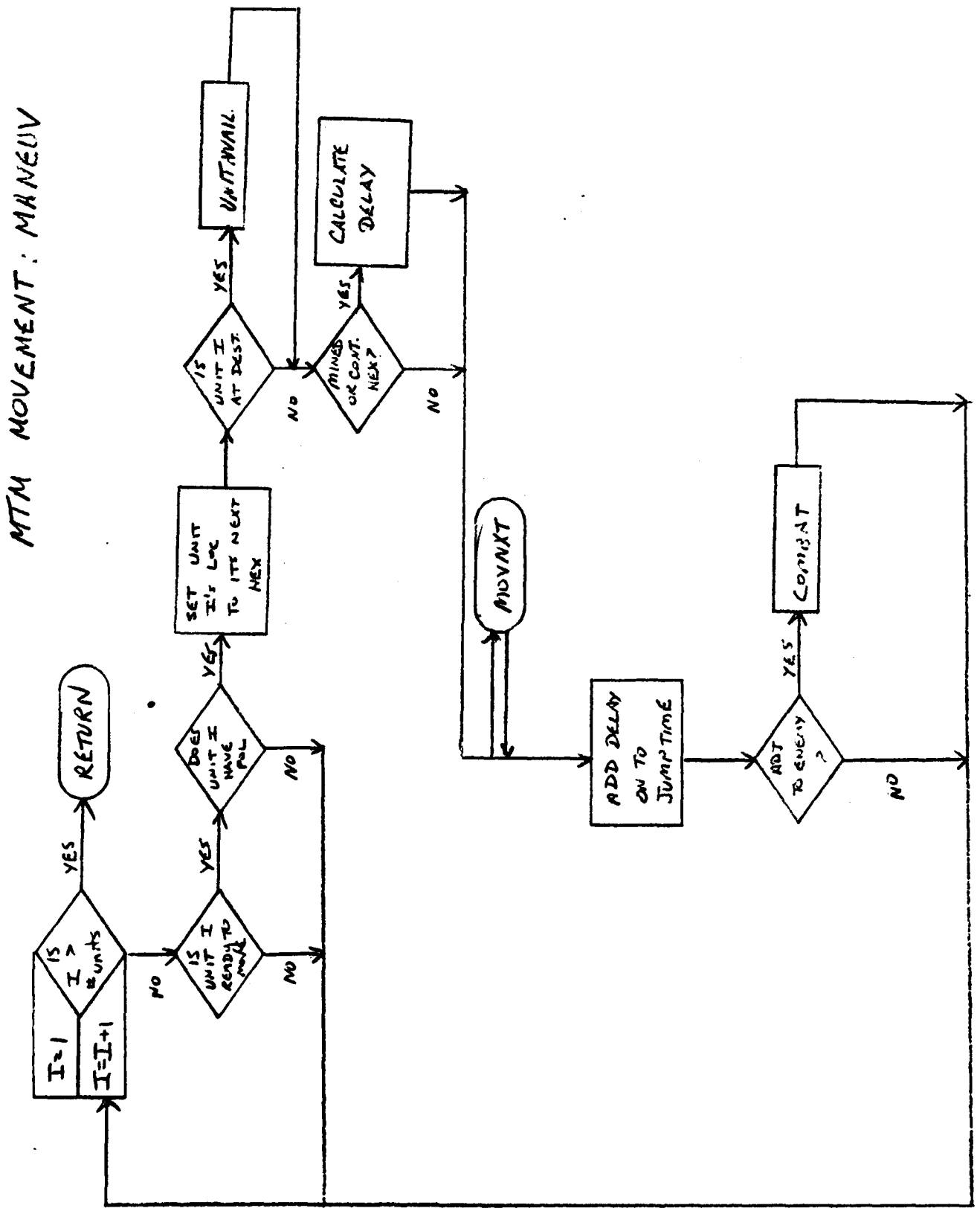
Appendix 1 a.

MTM MOVEMENT:

SUBROUTINE MOVORD

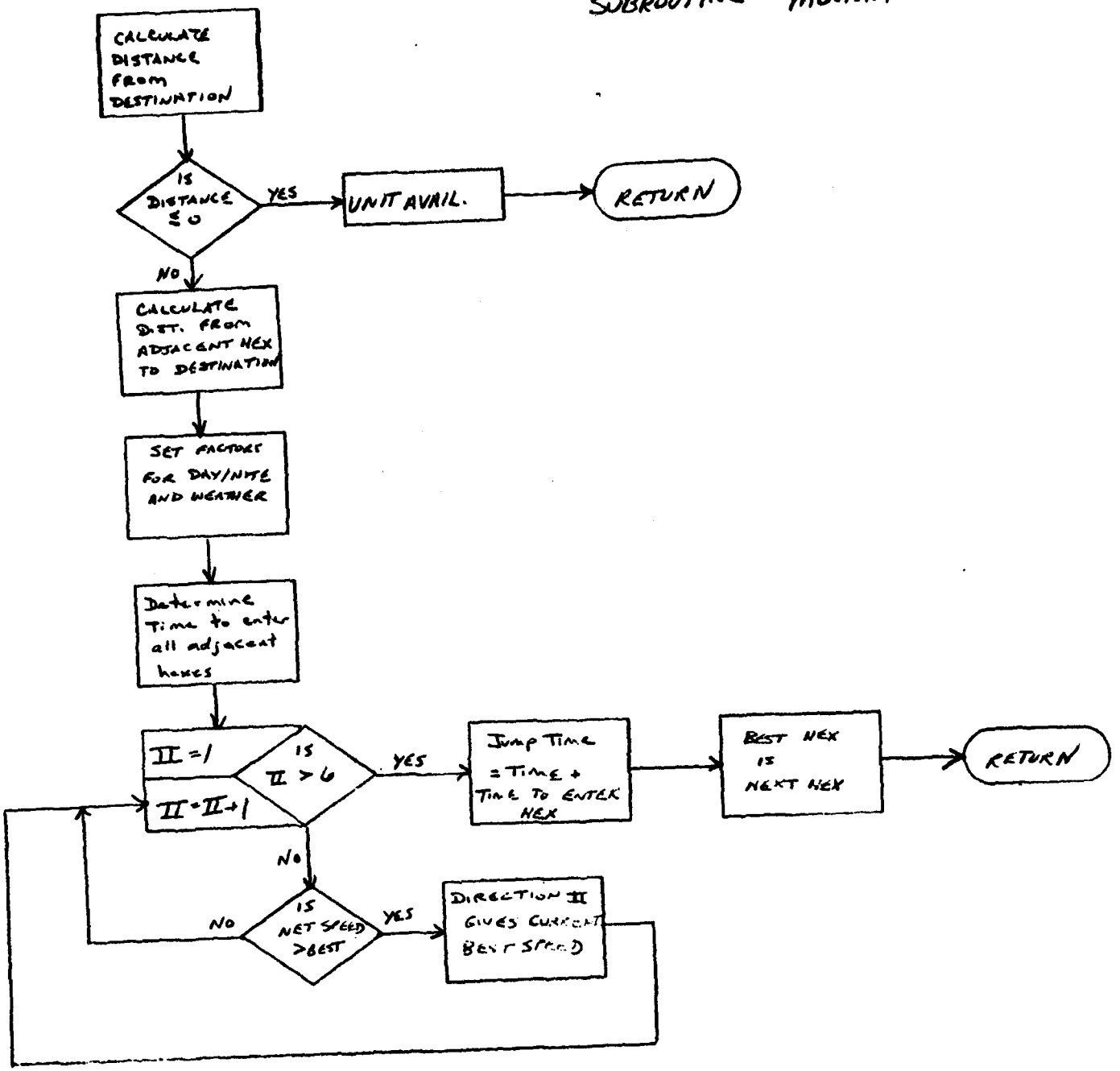


Appendix 1 b.


MTM MOVEMENT: MAINFRAME
I=1
I=I+1
IS I > # UNITS
YES
NO
RETURN
IS UNIT I READY TO MOVE
YES
NO
DOES UNIT I HAVE POL
YES
NO
SET UNIT I'S LOC TO ITS NEXT NEX
IS UNIT I AT DEST.
YES
NO
UNITAVAIL
MINES OR CONT. NEXT?
YES
NO
CALCULATE DELAY
MOVNXT
ADD DELAY ON TO JUMP TIME
ADJ TO ENEMY ?
YES
NO
COMBAT

Appendix 1 c.

MTM MOVEMENT
SUBROUTINE MOVNXT



MTM HISTORICAL MODELING:

PREPARATION OF THE KHARKOV DATABASE

ER489A report by

John S. Morris III

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I. INTRODUCTION.

The McClintic Theater Model (MTM) has been the subject of the USMA And Army War College (AWC) Model Validation Program (MVP). The purpose of MVP is to assist the AWC in providing combat model users with "confidence statements" about the outcomes obtained from MTM. This particular project is intended to allow a historically based investigation of the validity of the MTM model. This is to be accomplished by the Department of History, whose researchers will attempt to re-enact the Battle of Kharkov.

I. [ROBLEM STATEMENT.

My contribution to this portion of the MVP involved two major tasks. The first task was to make the necessary software modifications to the game to allow the History department researchers to simulate the Kharkov battle. The second task was to assist the History department researchers in running the game, obtain feedback from them on the games accuracy and make any modifications to the game that they believe will allow it to more closely simulate World War II conditions.

III. SOFTWARE MODIFICATIONS.

The first task required two major actions: prepare a properly formatted database for the Kharkov battle and then modify the game to accept this database if necessary. These tasks have been successfully completed.

Maj. Stille, USAF, and MAJ Hendrix were responsible for gathering the data for the Kharkov terrain data base.

This data was based on information obtained from World War II era maps of the Kharkov area. The terrain data consisted of two elements for each hex. These were the barrier data for each hexside and the terrain value for the hex. A comparison of their barrier and terrain designations and the MTM game's own designations is given along with their trafficablity effects in figure 1. This data was then placed into a file giving the hex designation, terrain value and the barrier data for each hex.

My task was to reformat this data into the form acceptable to the MTM program. However, before this could be done, I had to fill in missing hexes in order to form a rectangular map. Rather than fill these hexes with arbitrary values, I developed a reformatting program called SECOND.F77 that would create the missing hexes by copying data from the hex immediately to the south. The SECOND program produced the data for a 42 (E-W) by 48 (N-S) hex grid. The code for the SECOND.F77 program is included in ANNEX A.

MAJ Bonin of the Department of History was responsible for providing the unit data. His information was based on three publications from the World War II era. These references were: FM 105-5 Maneuver Control, TM 30-430 Handbook on USSR Forces and TM 30-451 Handbook on German Forces. The number of each type of weapons system in a particular type of unit such as a Rifle brigade was determeined from the Handbook. Each weapon's relative effectiveness was referenced in FM 105-5 and multiplied by

the number of weapons. The sum of these products was the generic unit's firepower score. The Unit strength was the firepower score divided by 1000. A particular unit's strength was the generic strength times the percent strength of the particular unit.

The artillery units damage per volley was determined by using the product of the number of tubes in the unit and the weight of each shell. This product was used in a formula developed by COL Dupuy USA (ret.) to determine the number of casualties produced. The number of vollies was the ammunition tonnage on hand divided by the tonnange fired per volley. The supply of direct fire ammunition was simply the total of the number of weapons times the ammunition carried per weapon in tons.

The movement rates were based on data provided in the TMs. The rates were a comnpromise between these rates and the rates given in the MTM Players Guides. Large unit's were given slightly slower movement rates to simulate the increased logistical tail and the fact that not every one is in the same kind of vehicle or even has a vehicle.

The data for each unit had to be loaded into the computer and properly formatted. The data was manually loaded into the computer and was automatically formatted using the FIRST.F77 program. This program code is listed in ANNEX B. The data for all 155 units in the game was entered using the FIRST program.

The total Kharkov database was created by combining the terrain data with the unit data. Hexsize data was copied

from the NATO data base and globally changed to 5 miles. The default values for game parameters such as the probability of certain type of weather or the time that logistics or intelligence reports are issued were copied from the NATO database. The major differences in the configuration of the two databases was the use of 184 instead of 306 rows of terrain and barrier data (a result of the smaller size of the Kharkov hexgrid), and the fact that only 155 units were included instead of 300.

These differences along with the fact that the History department did not include the first 10 hex rows in its grid, required that the game be modified slightly. The modifications required were relatively simple. In the INITL and UPDATE subroutines, the format, read and write statements had to be changed to account for the fact that only 155 units were in the data base and the Hex grid was a 42 by 48 rather than a 41 by 82 matrix. The changes were simply the direct substitution of 155, 42 and 48 for every reference to 300, 41 and 82 respectively in the read and write statements. The format statements were modified by substituting 155 and 184 for 300 and 306 in these statements. In all of the subroutines, wherever the was a reference to a particular hex, all references to the north south row were changed from NS/2 +1 to (NS-10)/2 to account for the fact that rows 1-10 are nonexistent. The NS variables were change by locating every NS type variable. These variables included NS(I), NSDEST(I), NSFIRE(I), NWT(I),NSNXT and NSNEXT(I). The (I) is the subscript for

the array and is the unit°s ID number.

The new data base was tested in the modified game. The game accepted the database without any problems. The game was then available for play testing.

The initial modifications to the game also included eliminating the defensive posture bias favoring red units and making air attack damage a function of the particular aircraft type. The posture bias involves the combat subroutine which puts the red units in a given posture sooner than a blue unit. This is unacceptable given the qualitative superiority of the German (blue) units over the Soviet (red) units during World War II. This was remedied by making the posture determinations the same for both sides. The air attack damage assessment was modified by making the game reference the DAMVOL(I) variable to read the damage done per sortie by the particular unit making the attack. The game originally used a set percentage to assess the damage.

IV. TESTING AND DEBUGGING THE PROGRAM.

Once the database was prepared and the game was modified, the next step was to have the D/Hist researchers play the game. This has yet to happen. The reason for this is that the time that was to be devoted to playing the game was instead spent debugging the program. The problems encountered were that the game developed subscript errors anytime a move movement order was given. With the assistance of Mr. Don Leech of ACD, I was able to trace the problem to the TRAFIC function and make a quick fix to

prevent the IDIGIT variable from being zero. In that event IDIGIT would be reset to one. Then the game would not execute movement orders. Instead it would give the unit "is confused as to best path- give intermediate destination" message. This occured even when the order was to move to an adjacent hex.

This problem proved impossible for me to correct within the time remaining in the semester. I made a temporary fix know as the "Shortest Path Algorithm" to allow units to move directly toward its destination if it is within six hexes east-west and north-south of its destination. This modification is listed as figure 2. With this Algorithm in place, the game is now operational.

V. RECOMMENDATIONS FOR FUTURE RESEARCH.

The major road block to future progress of the MVP is the lack of an operational source file for the game. The seg file is operational but it cannot be modified. Also the current source files may not be what the seg file contains. This may invalidate the results of code analysis. Therefore, a top priority should be to locate every copy of the MTM source code on disk or tape. Then every one should be tested until the operational source code is located. This will make life much easier in the future.

If the operational source code is not located, then the current MTMALL must be debugged. I would suggest that a two person team should be used to accomplish this task. One person should be expert at Fortran programming and on using the Prime computer, while the other one should be familiar

with how MTM is supposed to function.

Until an MTM source file becomes operational, the MVP will be dead in the water. The source file must completely match the seg file or it will be impossible to modify MTM.

FIGURE 1

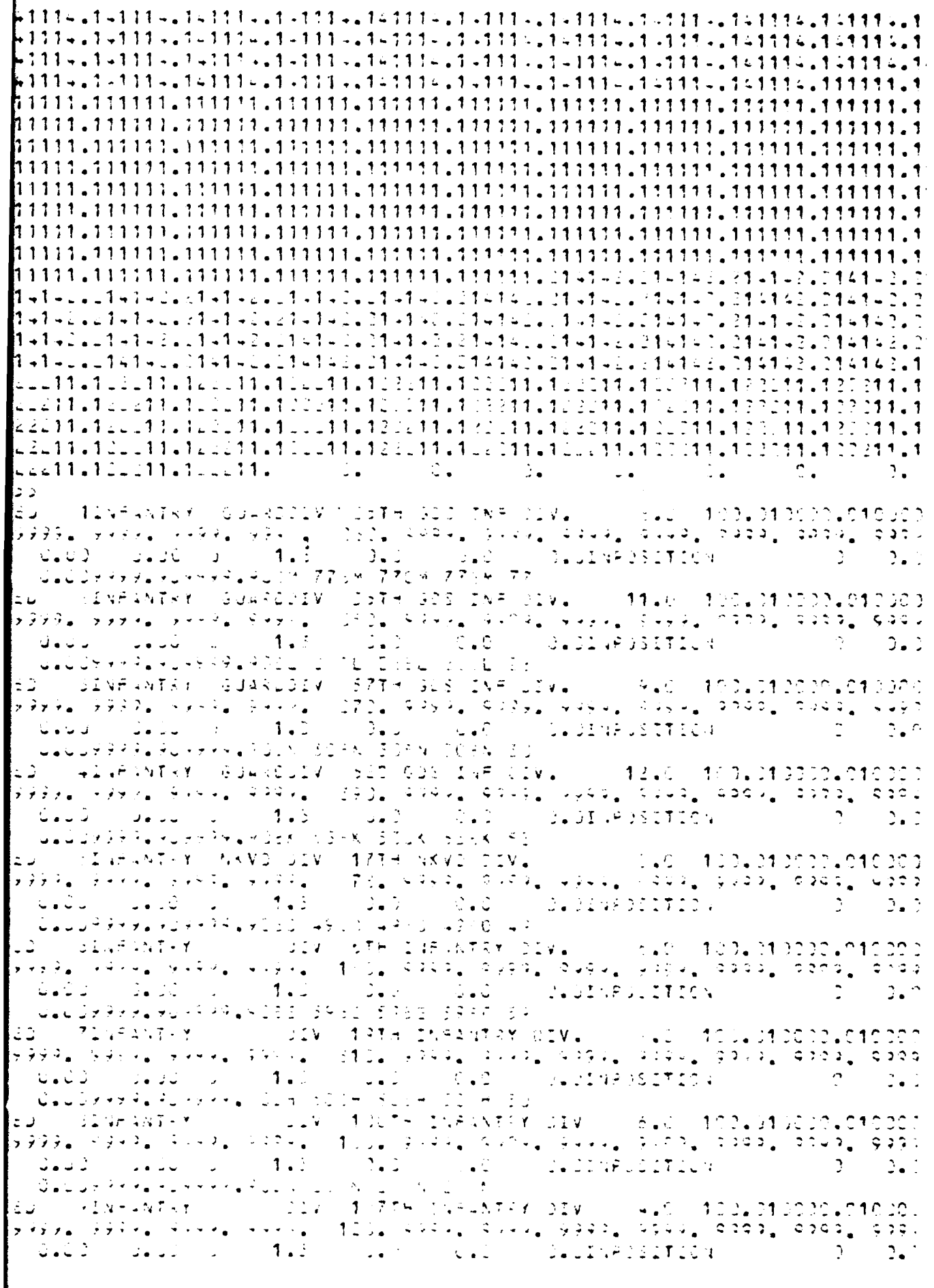
TERRAIN AND BARRIER DATA

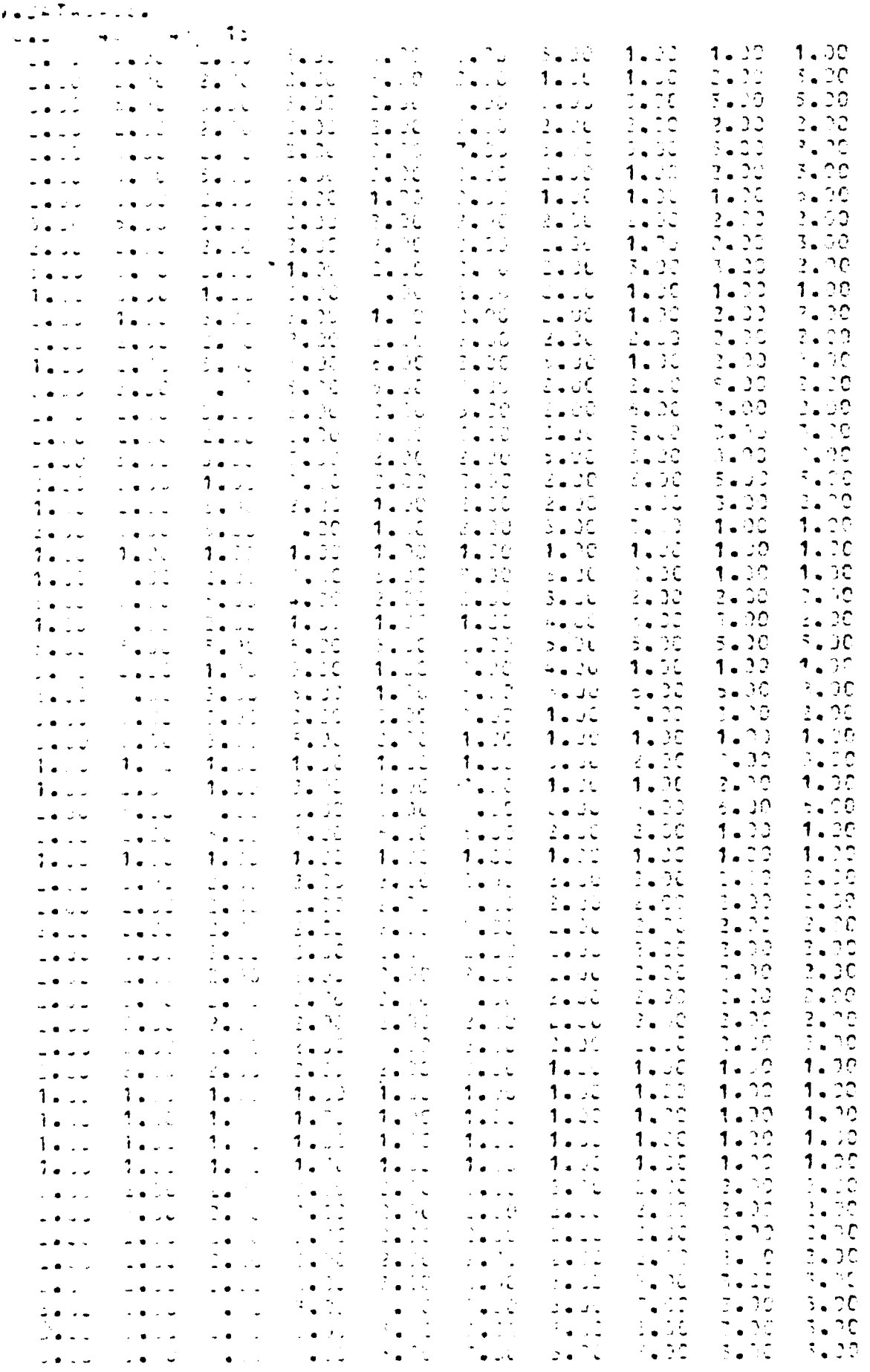
TERRAIN

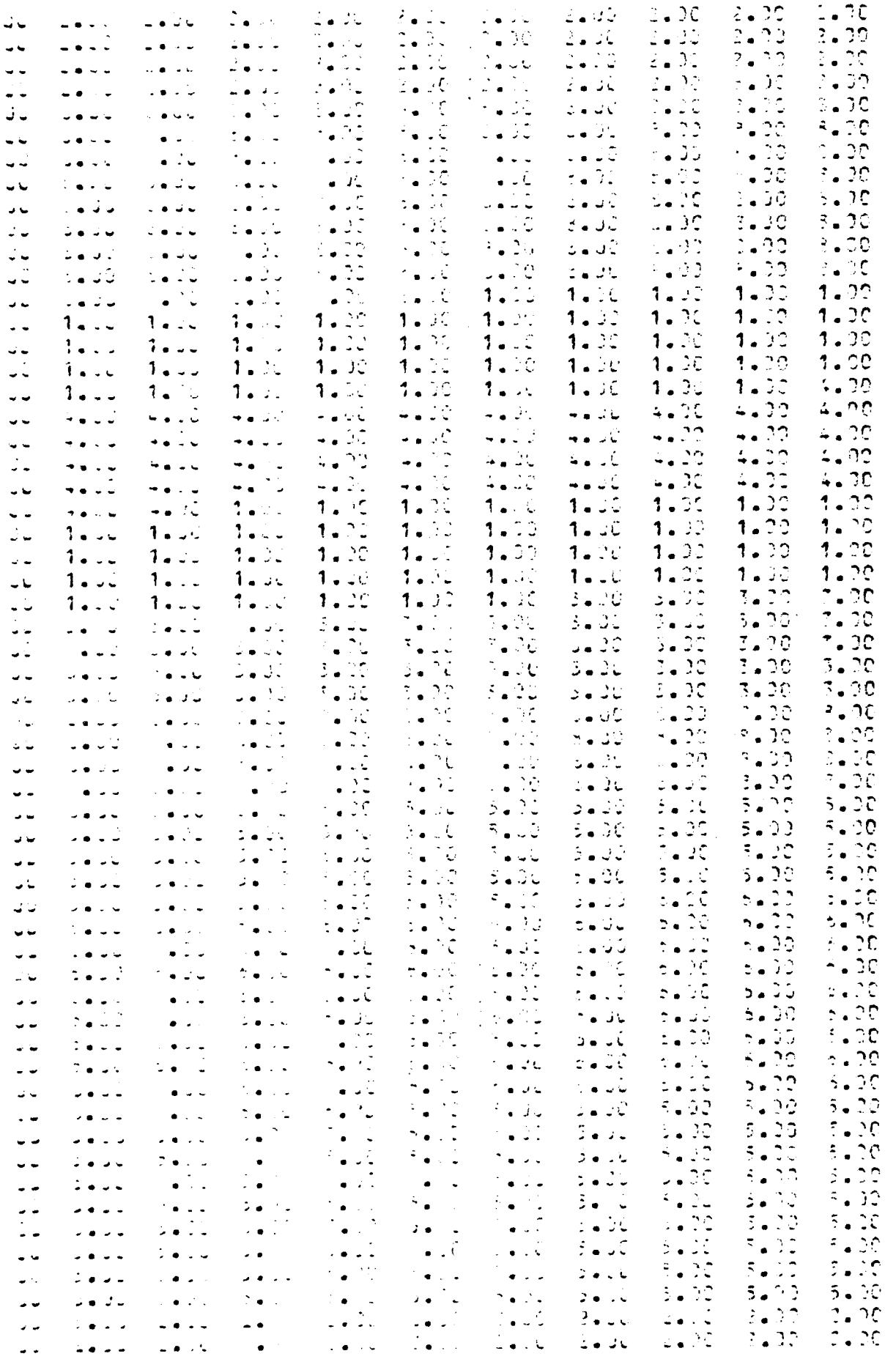
VALUE	MTM TYPE	KHARKOV	TRAFFIC
1	OPEN	OPEN	1.0
2	URBAN	VILLAGE	3.0
3	CITY	BUILT UP	3.0
4	-----	CITY/URBAN	4.0
5	MOUNTAINOUS	HILLS/DESERT	5.0
6	-----	FOREST/SWAMP	6.0
7	-----	ROUGH HILLS	7.0
9	-----	MOUNTAIN	9.0

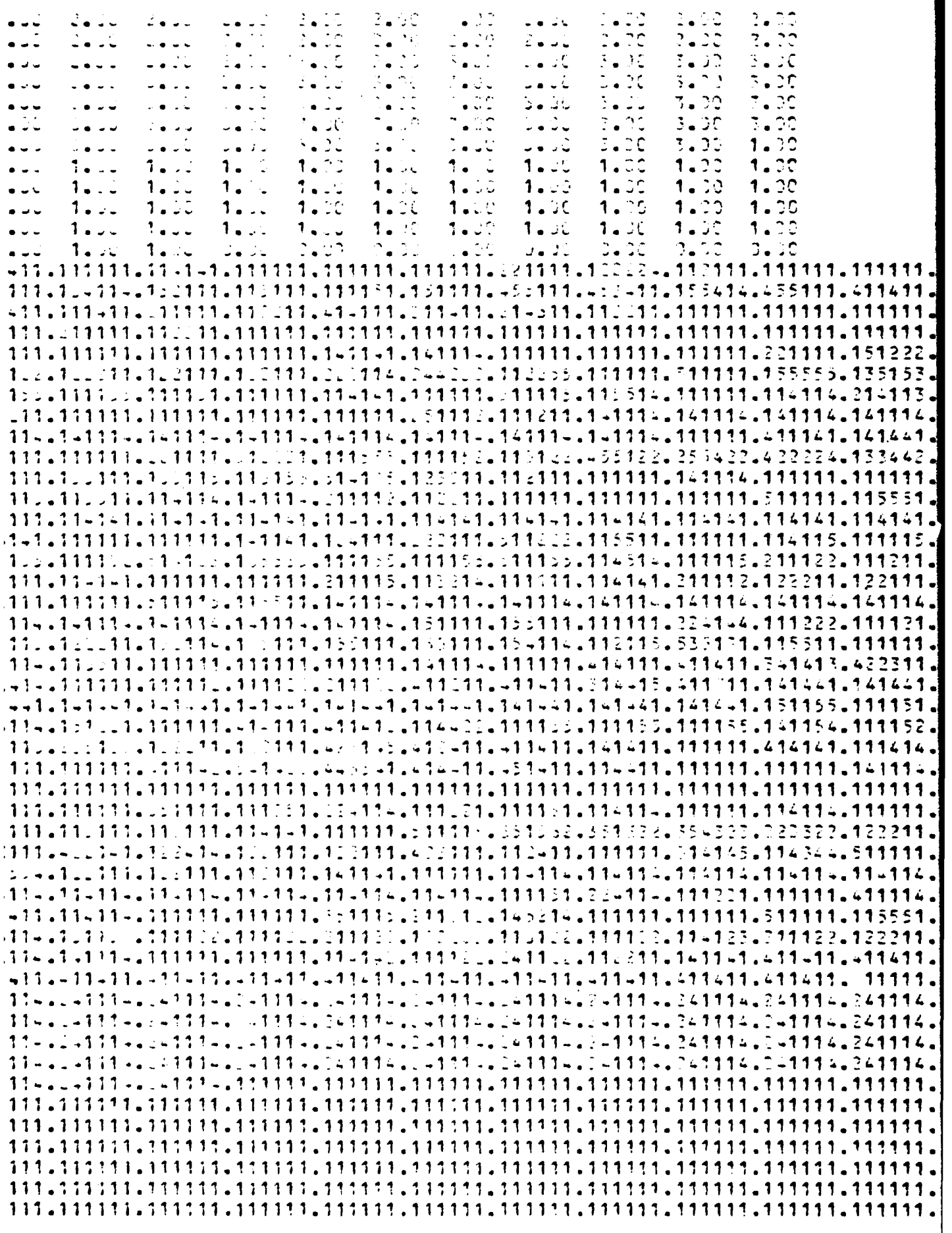
BARRIERS

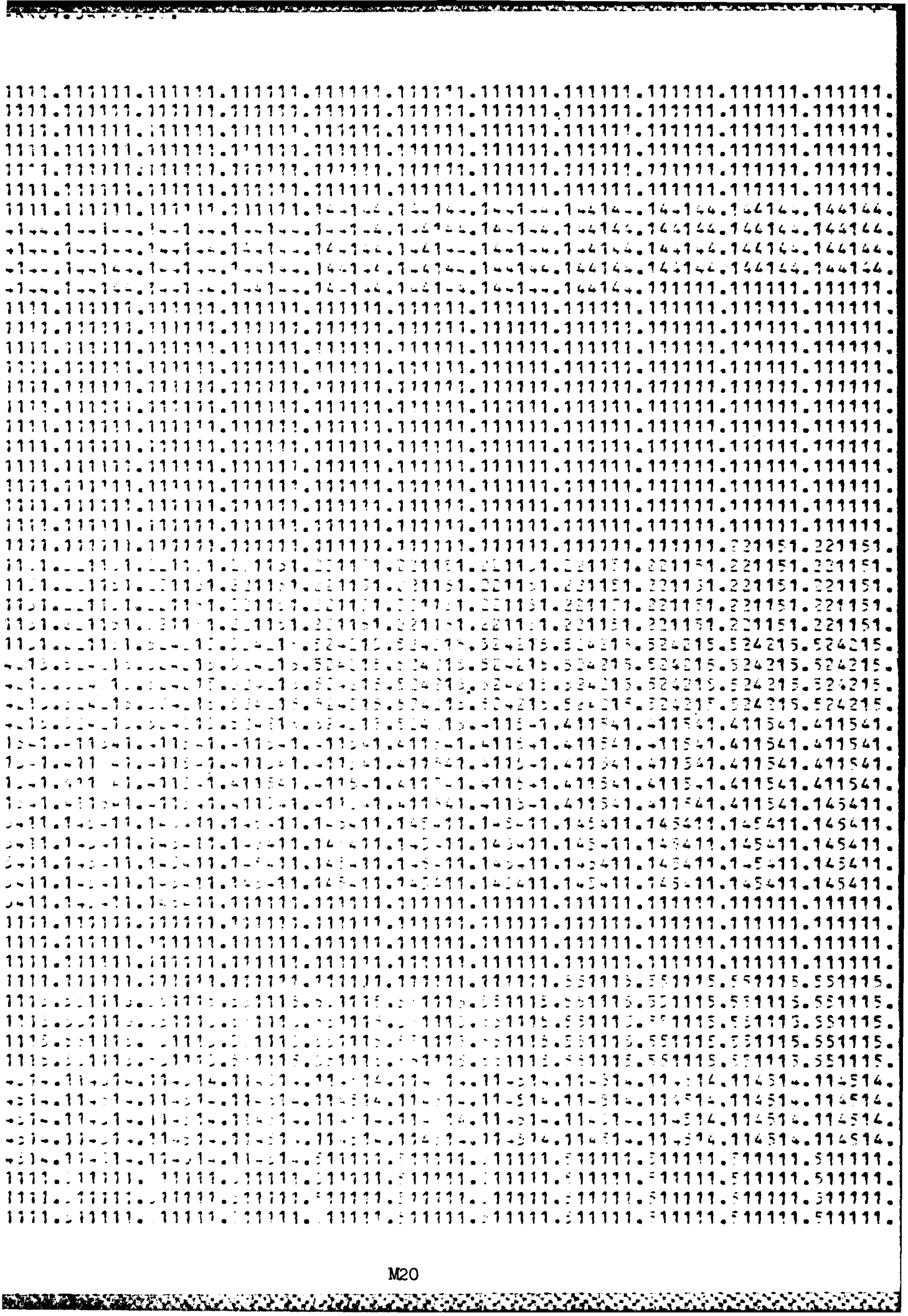
VALUE	MTM TYPE	KHARKOV	TRAFFICABILITY
1	NO BARRIER	NO BARRIER	1.00
2	RIVER	RIVER	3.00
3	BRIDGE	BRIDGE	0.5
4	ROAD	ROAD	0.5
5	----	SWAMP	0.33
6	----	-----	0.75
7	WADI	-----	3.00
8	AT DITCH	AT DITCH	3.00
9	IMPASSIBLE	IMPASSIBLE	99999.00

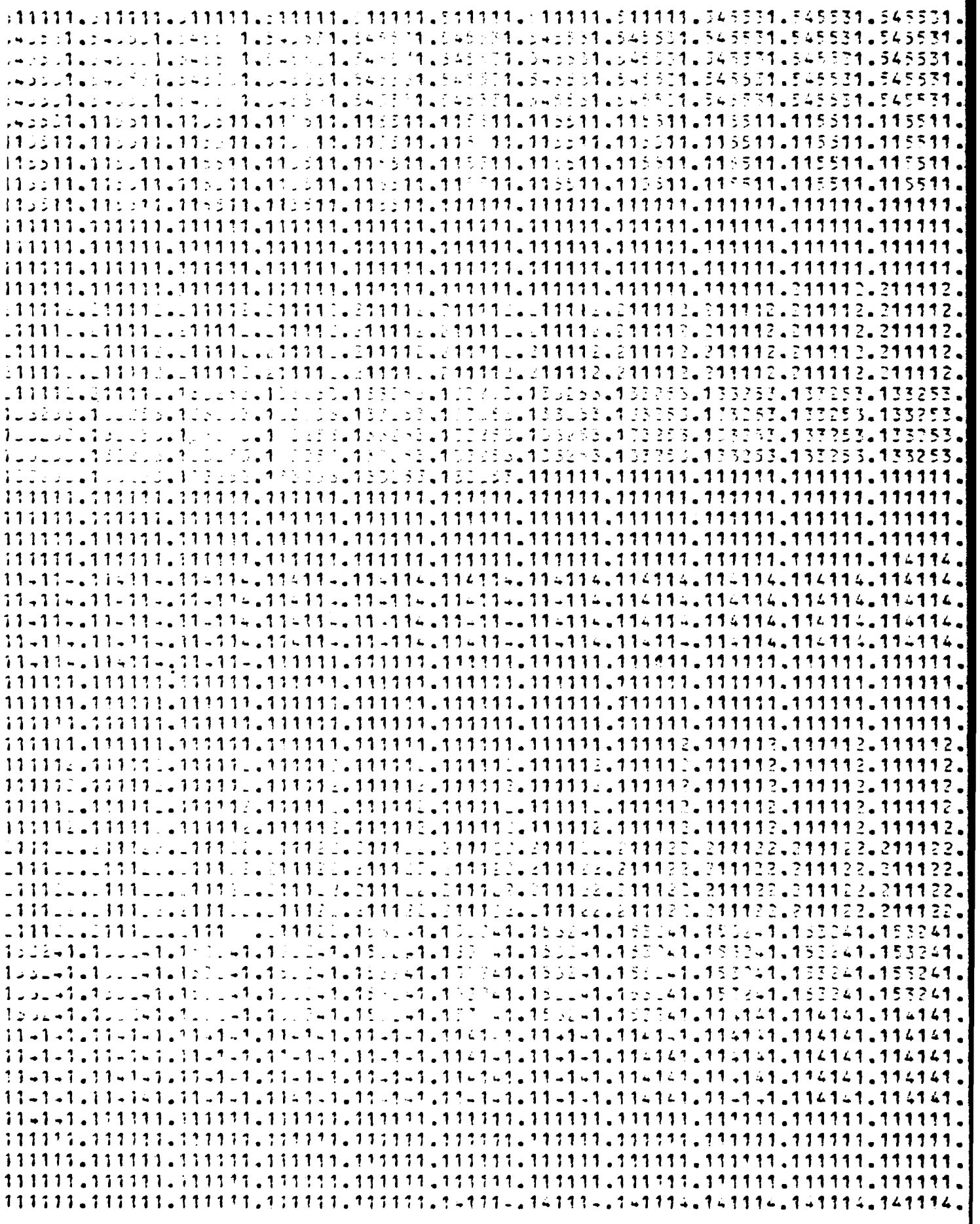












```
      READ(*,307) SPDMAX(I)
  107 FORMAT(F7.2)
  207 FORMAT(F7.2)
  307 FORMAT(F7.1)
      WRITE(*,108)
  108 FORMAT('ENTER RANGE, AIRSPEED AND ATTACK TYPE.')
      READ(*,109) RANGE(I)
      READ(*,309) AIRSPD(I)
      READ(*,209) ATYPE(I)
  109 FORMAT(F7.1)
  309 FORMAT(F7.1)
  209 FORMAT(A7)

      WRITE(*,110)
  110 FORMAT('ENTER THRESHOLD, EW LOC. AND NS LOC.')
      READ(*,111) THRESH(I)
      READ(*,211) EW(I)
      READ(*,311) NS(I)
  111 FORMAT(F7.2)
  211 FORMAT(A2)
  311 FORMAT(I3)
      EWNEXT(I)=EW(I)
      NSNEXT(I)=NS(I)
      EWDEST(I)=EW(I)
      NSDEST(I)=NS(I)
      EWFIRE(I)=EW(I)
      NSFIRE(I)=NS(I)

   30   CONTINUE

C     THIS SECTION WRITES THE DATA TO THE FILE.

  200 FORMAT(A4,I3,A10,2A5,A18,5F7.1/ 12F6.0/ 2F7.2,I3,4F7.1,A10,A7,I3,
     12F7.2/
     13F7.2,A2,I3,A2,I3,A2,I3,A2,I3/)

      DO 300 L=M,N
      WRITE(10,200) UNITCL(L),NUNIT(L),UNITYP(L),SUBTYP(L),SIZE(L),
     1NAME(L),POINTS(L),PERCNT(L),TOEPER(L),PERSON(L),CARRY(L),
     1SUPPLY(L,1),SUPPLY(L,2),SUPPLY(L,3),SUPPLY(L,4),SUPPLY(L,5),
     1SUPPLY(L,6),SUPPLY(L,7),SUPPLY(L,8),SUPPLY(L,9),SUPPLY(L,10),
     1SUPPLY(L,11),SUPPLY(L,12),AIRCFT(L),DAMVOL(L),NUMVOL(L),SPDMAX(L),
     1SPEED(L),AIRSPD(L),RANGE(L),POSTUR(L),ATYPE(L),ESCORT(L),TSEAD(L),
     1THRESH(L),ARTIME(L),TJUMP(L),TFIRE(L),EW(L),NS(L),EWNEXT(L),
     1NSNEXT(L),EWDEST(L),NSDEST(L),EWFIRE(L),NSFIRE(L)
      WRITE(*,200)
  300 CONTINUE
      WRITE(*,400)
  400 FORMAT('I AM FINISHED.')
      END
OK, '
```

```
C       INPUT THE DEFAULT VALUES
        DO 10 K=1,300
         DO 20 J=1,12
         SUPPLY(K,J)=9999
   20    CONTINUE
         PERCNT(K)=100.00
         TOEPER(K)=10000.0
         PERSON(K)=10000.0
         CARRY(K)= 10000.0
         ESCORT(K)=  0
         TSEAD(K)= 0.0
         THRESH(K)=0.0
         ARTIME(K)=0.0
         TJUMP(K)=9999.9
         TFIRE(K)=9999.9
         POSTUR(K)='INPOSITION'
   10    CONTINUE
         WRITE(*,90)
   90    FORMAT('ENTER THE FIRST UNIT NUMBER AND THE LAST NUMBER.')
         READ(*,91)M,N
   91    FORMAT(I3,I3)

C       INTERACTIVE INPUT SECTION
         WRITE(*,92)
    92   FORMAT('ENTER THE DATA ONE ITEM AT A TIME.')

         DO 30 I=M,N
         WRITE(*,100)
   100   FORMAT('ENTER UNIT COLOR,UNIT NUMBER, AND UNIT TYPE')
         READ(*,101) UNITCL(I)
         READ(*,201) NUNIT(I)
         READ(*,301) UNITYP(I)
   101   FORMAT(A4)
   201   FORMAT(I3)
   301   FORMAT(A10)
         WRITE(*,102)
   102   FORMAT('ENTER SUBTYPE, SIZE AND NAME.')
         READ(*,103) SUBTYP(I)
         READ(*,203) SIZE(I)
         READ(*,303) NAME(I)
   103   FORMAT(A5)
   203   FORMAT(A5)
   303   FORMAT(A18)
         WRITE(*,104)
   104   FORMAT('ENTER THE POINTS, SUPPLY V AND AIRCRAFT.')
         READ(*,105) POINTS(I)
         READ(*,205) SUPPLY(I,5)
         READ(*,305) AIRCFT(I)
   105   FORMAT (F7.1)
   205   FORMAT (F6.0)
   305   FORMAT (F7.2)
         WRITE(*,106)
   106   FORMAT('ENTER DAMVOL,NUMVOL AND SPDMAX.')
         READ(*,107) DAMVOL(I)
         READ(*,207) NUMVOL(I)
```

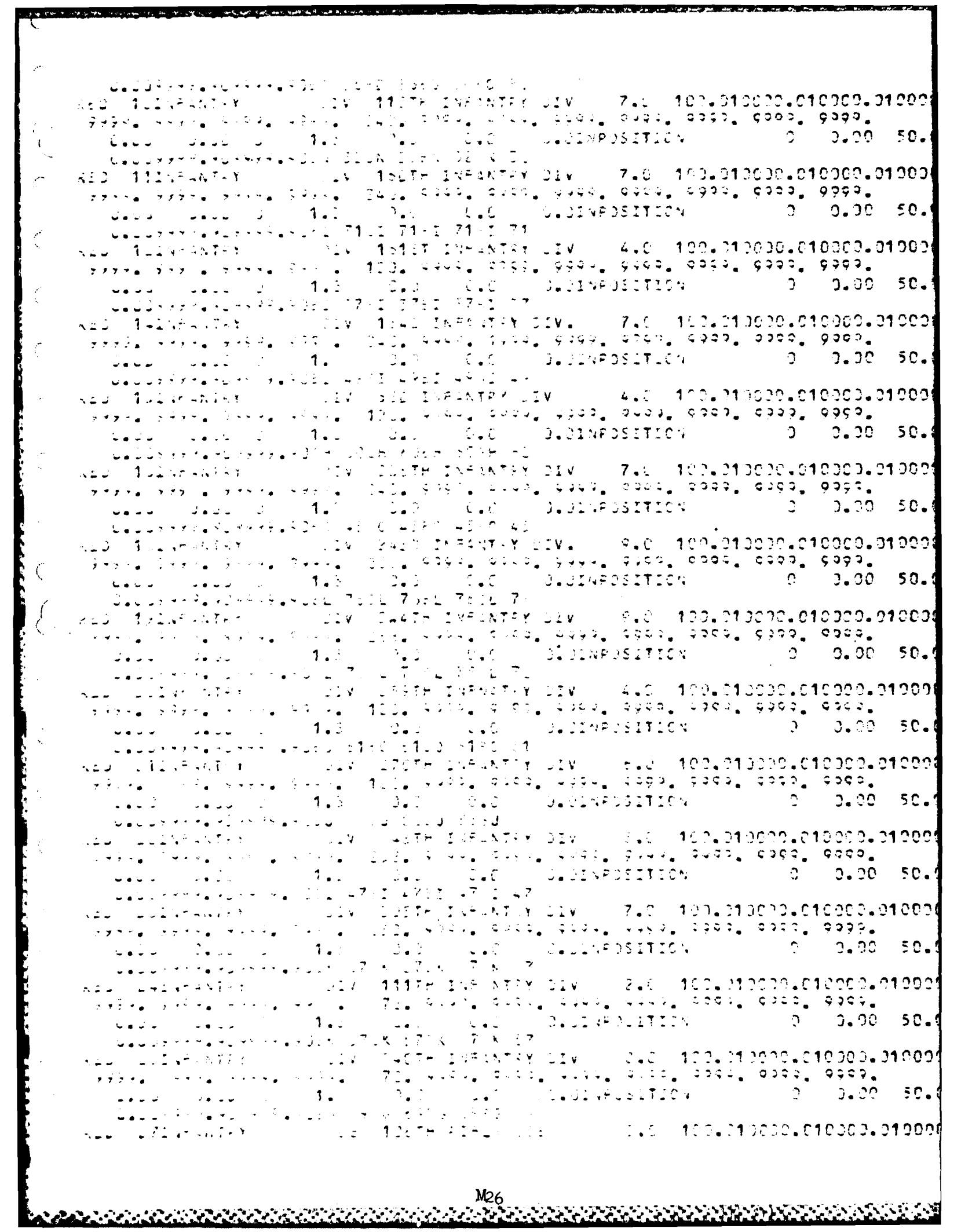
```
SLIST FIRST.F77
C      DATA INPUT PROGRAM
C
C      THIS PROGRAM ALLOWS A USER TO CREATE THE UNIT PORTION
C      OF AN MTM DATABASE.
*
C      DIMENSION VARIABLES
       COMMON /TERAIN/ TER(82,55), BAR(82,55), BARIER(9)
       COMMON /UNIT/NUNIT(300),NAME(300),UNITYP(300),UNITCL(300),EW(300),
      1 NS(300),ARTIME(300),PERCNT(300),POINTS(300),SPDMAX(300),
      2 POSTUR(300),EWDEST(300),NSDEST(300),TJUMP(300),EWNEXT(300),
      3 NSNEXT(300),SPEED(300),NUMVOL(300),RANGE(300),WARN(300),
      4 TSEAD(300),ATYPE(300),ESCORT(300),THRESH(300),AIRSPD(300),
      5 SUBTYP(300),SIZE(300),TOEPER(300),PERSON(300),CARRY(300),
      6 SUPPLY(300,12),AIRCFT(300),DAMVOL(300),TFIRE(300),EWFIRE(300),
      7 NSFIRE(300),ORIENT(300),ETA(300),TBUSY(300),PROTECT(300)
       COMMON /OTHER/NUMBER,ASTIME,FACTOR,SUNRIS,SUNSET,BCLOCK,
      + DIMEW,DIMNS,DIMUNT,TITLE,EWJAMR,
      1 EWJAMB,EWINTR,EWINTB,POLCON,POLSOR,AMOSOR,AMOVOL,BATTIM,NBATL,
      2 NUCBLU,NUCRED,ICHEMB,ICHEMR,DAYNIT,WX,WXFACT,WXTIME,PFOG(4),
      3 PRAIN(4),PDDCLR,PDDFOG,PDDRAN,PDNCLR,PDNFOG,PDNRAN,TRACE,
      4 TIMEL,TIMLST,TIMLOG,BLUNAT,REDNAT,BNATIN,BNATD,BNATPD,BNATPI,
      5 BNATPA,RNATIN,RNATD,RNATPD,RNATPI,RNATPA,HEXSIZ(164),NBINIT,
      6 FRTALY(30),NUCH,EWCHG,NSCHG,UNITCH,IDLECL(12),MOVECL(12),
      7 MODECL(12),COMBCL(12),SEED
*
       CHARACTER*2 EW,EWDEST,EWFIRE,EWNEXT,EWCHG,ORIENT
       CHARACTER*4 UNITCL,DAYNIT
       CHARACTER*5 SUBTYP,SIZE
       CHARACTER*7 ATYPE
       CHARACTER*8 DAY,WX
       CHARACTER*10 UNITYP,POSTUR
       CHARACTER*18 NAME
       CHARACTER*24 FORMT,FORMB
       CHARACTER*80 TITLE
       CHARACTER*108 FORMU
       DIMENSION DUMMY(4),RUMMY(4)
       INTEGER ESCORT,DIMEW,DIMNS,DIMUNT
       CHARACTER*3 STAX
       CHARACTER*5 FILE

       LOGICAL WARN,EX2

C      OPEN THE FILE

       INQUIRE(FILE='UDATA',EXIST=EX2)
       IF (EX2) THEN
       STAX='OLD'
       ELSE
       STAX='NEW'
       END IF
```

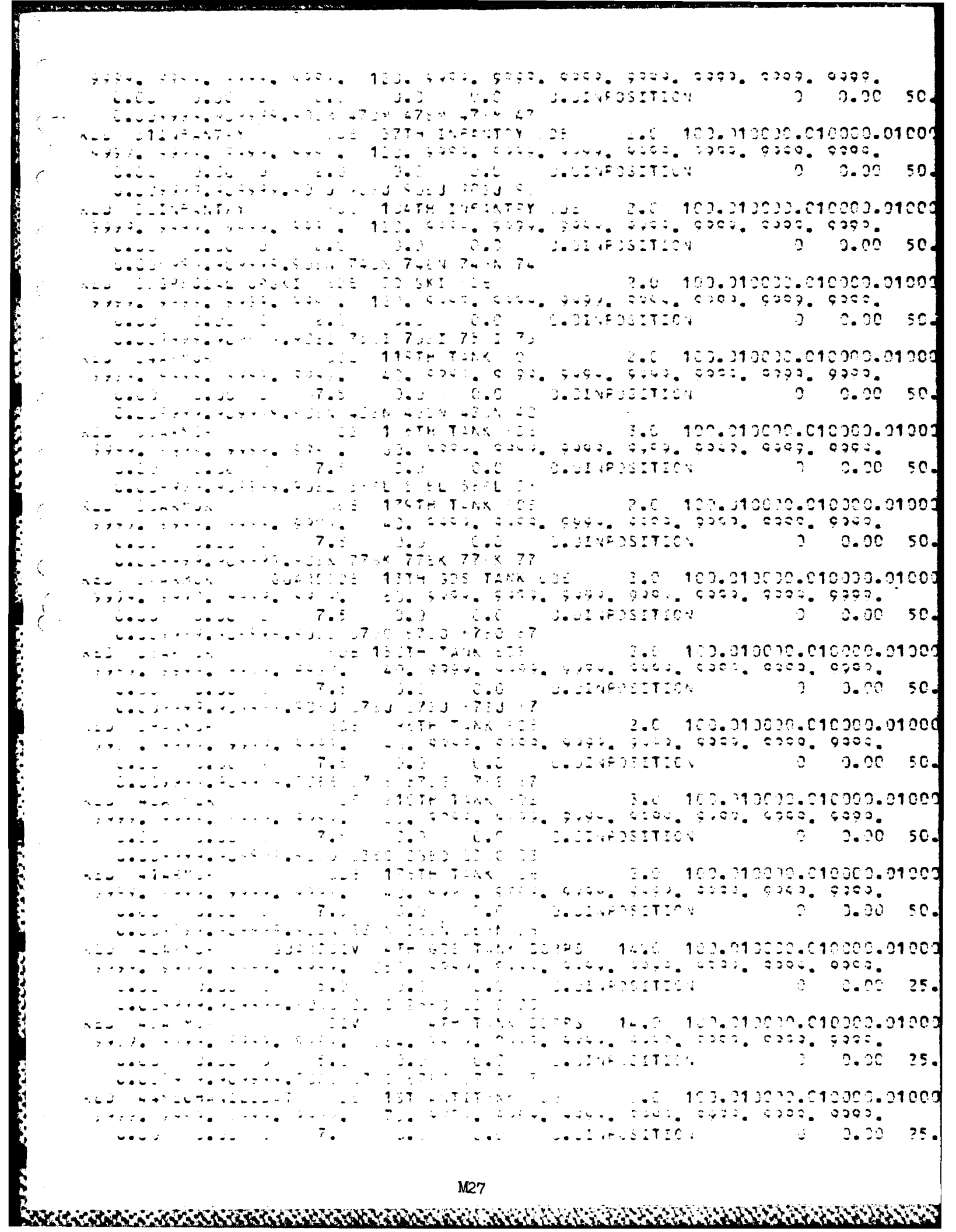
```
C      WRITE SECTION
C      Writes the data in the matrix format.
       WRITE(6,200)((TER(2*K+9+(1+(-1)**J)/2,J),K=1,48),J=1,42),
      1(RUMMY(M),M=1,8),((BAR(2*K+9+(1+(-1)**J)/2,J),K=1,48),J=1,42),
      2(DUMMY(M),M=1,8),N
  200 FORMAT(184(11F6.2/),184(11F7.0/),I3/)
       END
OK,
```

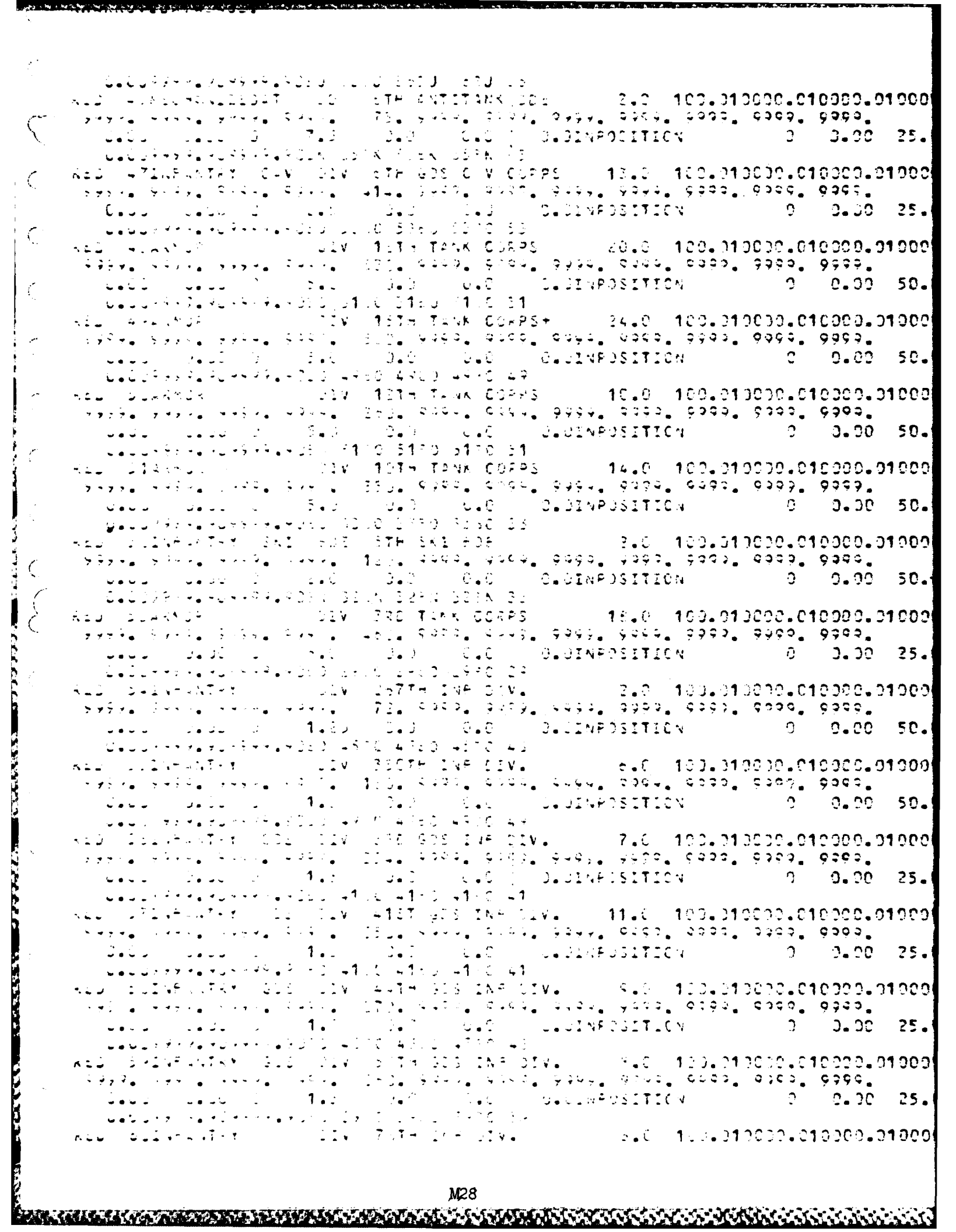
```
SL$ST SECOND.F77
C2345678
C       DIMENSION SECTION
        INTEGER NS(108),TER(108,42),BAR(108,42),RUMMY(8),DUMMY(8)
        INTEGER TNS,TTER,TBAR,FLAG,RAG
        CHARACTER EW(42)*2,TEW*2,COMMA*1

C       FILE SECTION
        OPEN (5,FILE='K.DATA',STATUS='OLD')
        OPEN (6,FILE='TDATA.KHAR',STATUS='NEW')

C       TERRAIN READ AND EXPANSION SECTION
C       This section reads the data from Terrain.khar and fills in
C       representative terrain for missing hexes. 42(EW)x48(NS).

        NS(10)=10
        NS(11)=11
        DO 1 J=1,8
        DUMMY(J)=0
        RUMMY(J)=0
      1 CONTINUE
        FLAG=0
        RAG=0
        DO 20 J=1,42
         L=1+(1+((-1)**J))/2
         RAG=RAG+1
         DO 10 K=1,48
          I=2*K+8+L
      2   IF (RAG.EQ.2)  GOTO 40
           IF (FLAG.EQ.0)  GOTO 5
            NS(I)=NS(I-2)+2
            TER(I,J)=TER(I-2,J)
            BAR(I,J)=BAR(I-2,J)
           GOTO 10
      5    READ(5,100) EW(J),NS(I),COMMA,TER(I,J),COMMA,BAR(I,J)
           RAG=0
           IF (NS(I).EQ.I)  GOTO 10
            FLAG=1
            RAG=1
            TNS=NS(I)
            TEW=EW(J)
            TBAR=BAR(I,J)
            TTER=TER(I,J)
           GOTO 2
     40   RAG=0
          EW(J)=TEW
          NS(I)=TNS
          TER(I,J)=TTER
          BAR(I,J)=TBAR
          WRITE(1,100)EW(J),NS(I),COMMA,TER(I,J),COMMA,BAR(I,J)
     10   CONTINUE
          FLAG=0
     20 CONTINUE
    100 FORMAT(A2,I3,A1,I1,A1,I6)
```

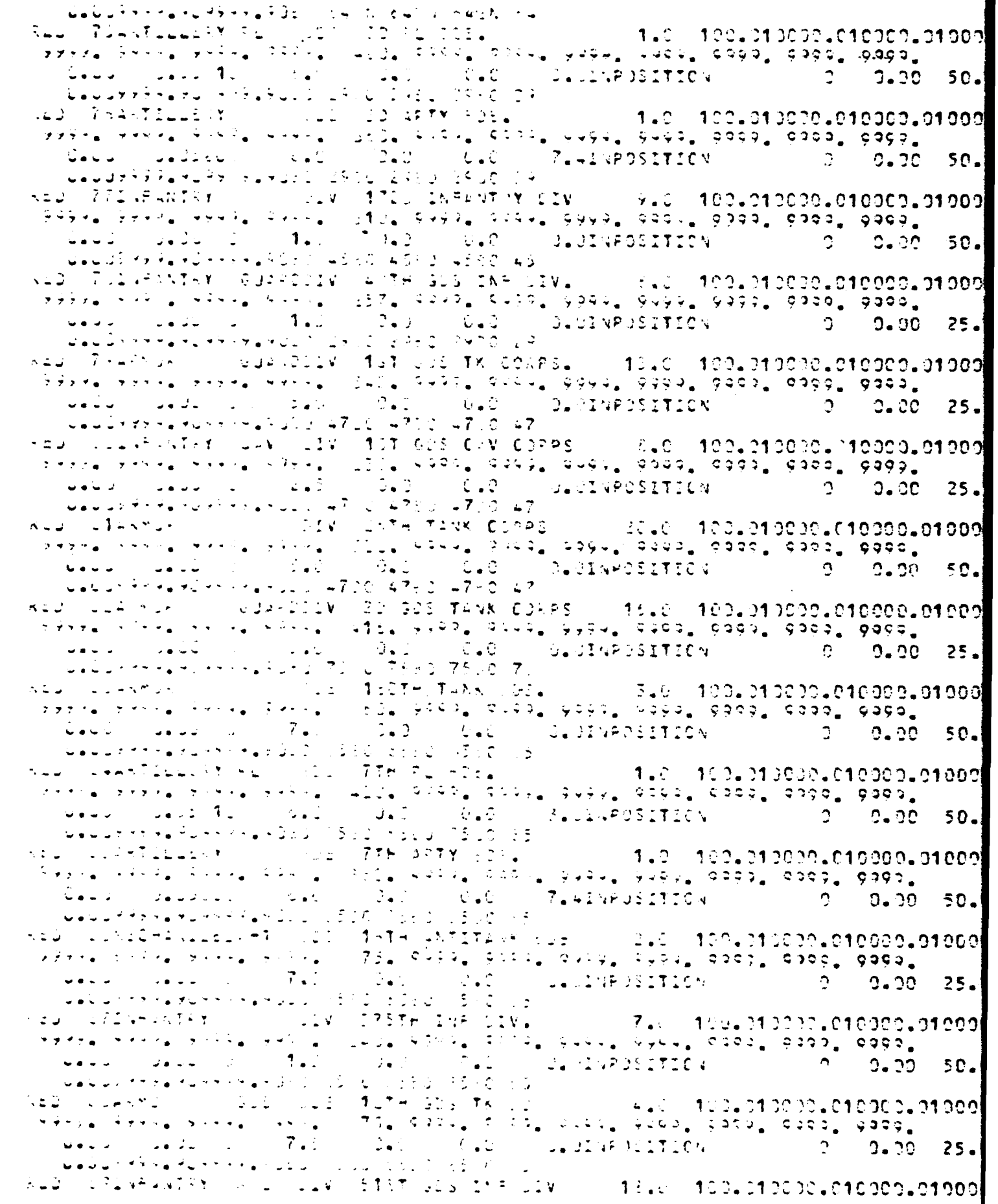
```
      END IF
      IF (ISHORT.EQ.3) THEN
       POSTUR(I)='MOVING SE '
      END IF
      IF (ISHORT.EQ.4) THEN
       POSTUR(I)='MOVING S  '
      END IF
      IF (ISHORT.EQ.5) THEN
       POSTUR(I)='MOVING SW '
      END IF
      IF (ISHORT.EQ.6) THEN
       POSTUR(I)='MOVING NW '
      END IF
      TJUMP(I)=(HOWFAR(EW(I),NS(I),EWNEXT(I),NSNEXT(I))/SPEED(I))+TIME
      DIST=HOWFAR(EW(I),NS(I),EWNEXT(I),NSNEXT(I))
      WRITE(OUTPUT,224)NUNIT(I)
      PRINT*,'SHORTEST PATH ALGORITHM ACTIVATED,'
      PRINT*,'DEST',EWNEXT(I),NSDEST(I)
      PRINT*,'TIME',TJUMP(I)
      PRINT*,'DISTANCE=',DIST
      PRINT*,'SPEED=',SPEED(I)
      WRITE(OUTPUT,225)
224   FORMAT(' #',I3,'IS CONFUSED ON BEST PATH-')
225   FORMAT('UNIT IS MOVING BY DIRECT ROUTE')
      GOTO 47
```

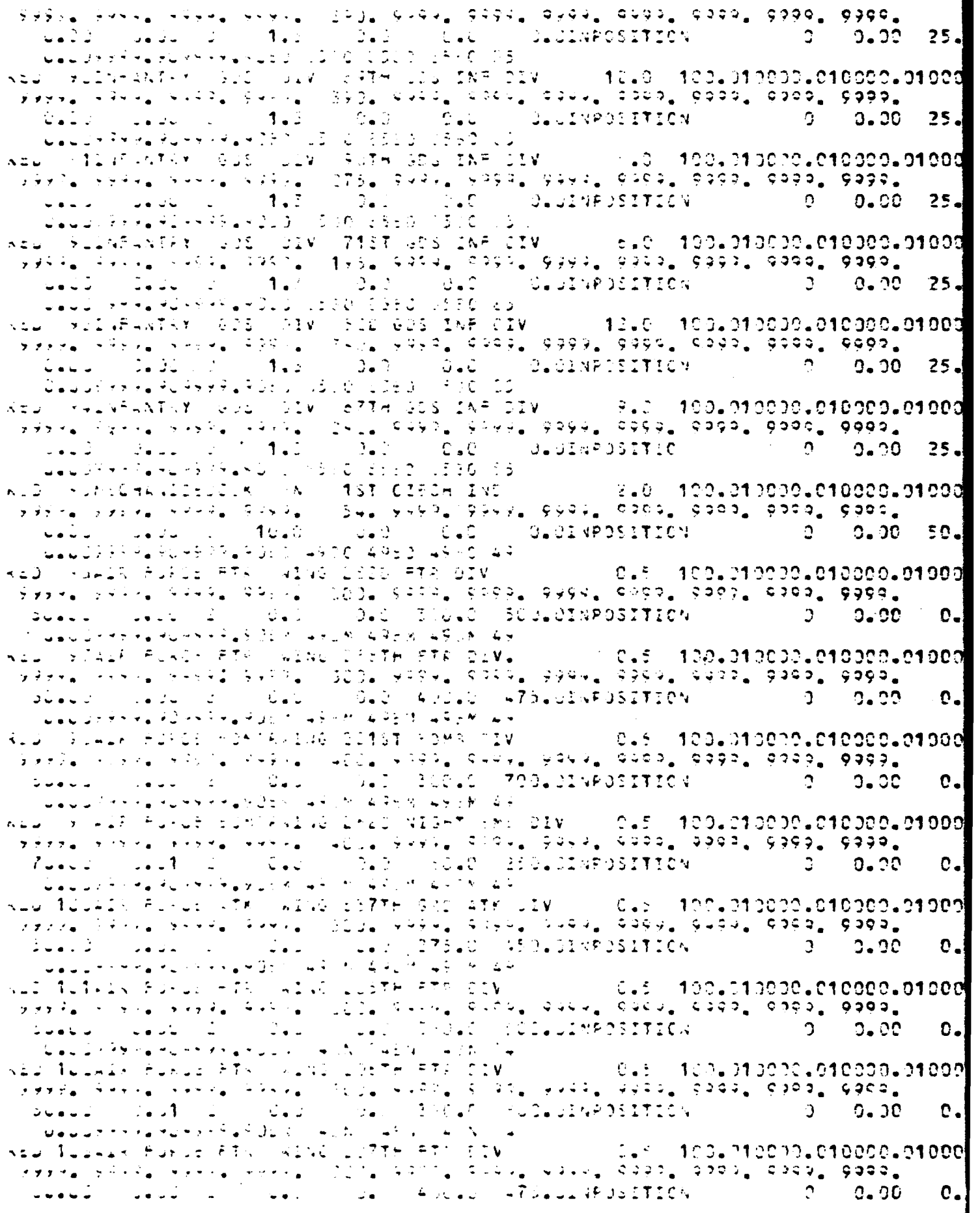
```
C      ADDITION TO MAKE UNITS MOVE BY SHORTEST PATH IF REQUIRED.
C
C      ********** SHORTEST PATH ALGORITHYM **********************
C
36     ISUMA=IABS(NSDEST(I)-NS(I))
       IPARA= NEW(EWDEST(I))
       IPARB= NEW(EW(I))
       ISUMB=IABS(IPARA-IPARB)
       IF (ISUMA .GT. 6 .OR. ISUMB .GT. 6) GOTO 136
       PRINT*,'SPA'
       IF(TYPE .EQ. 'AIR' )GOTO 35
C234567 THIS CHANGES EW NUMBERS TO CHARACTERS.
       DATA EWNM /'AA','AB','AC','AD','AE','AF','AG','AH','AI',
      1           'AJ','AK','AL','AM','AN','AO','AP','AQ','AR',
      2           'AS','AT','AU','AV','AW','AX','AY','AZ',
      3           'BA','BB','BC','BD','BE','BF','BG','BH','BI',
      4           'BJ','BK','BL','BM','BN','BO','BP','BQ'/
C      FIND DIRECTION OF TRAVEL.
       EWNEXT(I)=EWNM(NEW(EW(I))-1)
       IEW=-1
       IF(EW(I).EQ.EWDEST(I)) THEN
          EWNEXT(I)=EW(I)
          IEW=0
       END IF
       IF(NEW(EW(I)).LT.NEW(EWDEST(I))) THEN
         EWNEXT(I)=EWNM(NEW(EWDEST(I))+1)
         IEW=1
       END IF
       IF (NS(I).EQ.NSDEST(I)) THEN
        IF (EW(I).NE.EWDEST(I)) THEN
          NSNEXT(I)=NS(I)+1
          ISHORT=4-(2*IEW)
        END IF
       END IF
       IF (NS(I).GT.NSDEST(I)) THEN
         NSNEXT(I)=NS(I)-1
         ISHORT=4-IEW
        IF (EW(I).EQ.EWDEST(I)) THEN
         NSNEXT(I)=NS(I)-2
         ISHORT=4
        END IF
       END IF
       IF (NS(I).LT.NSDEST(I)) THEN
          NSNEXT(I)=NS(I)+1
          ISHORT=4-(2*IEW)
        IF (EW(I).EQ.EWDEST(I)) THEN
         NSNEXT(I)=NS(I)+2
         ISHORT=1
        END IF
       END IF
       IF (ISHORT.EQ.1) THEN
        POSTUR(I)='MOVING N  '
       END IF
       IF (ISHORT.EQ.2) THEN
        POSTUR(I)='MOVING NE '
```

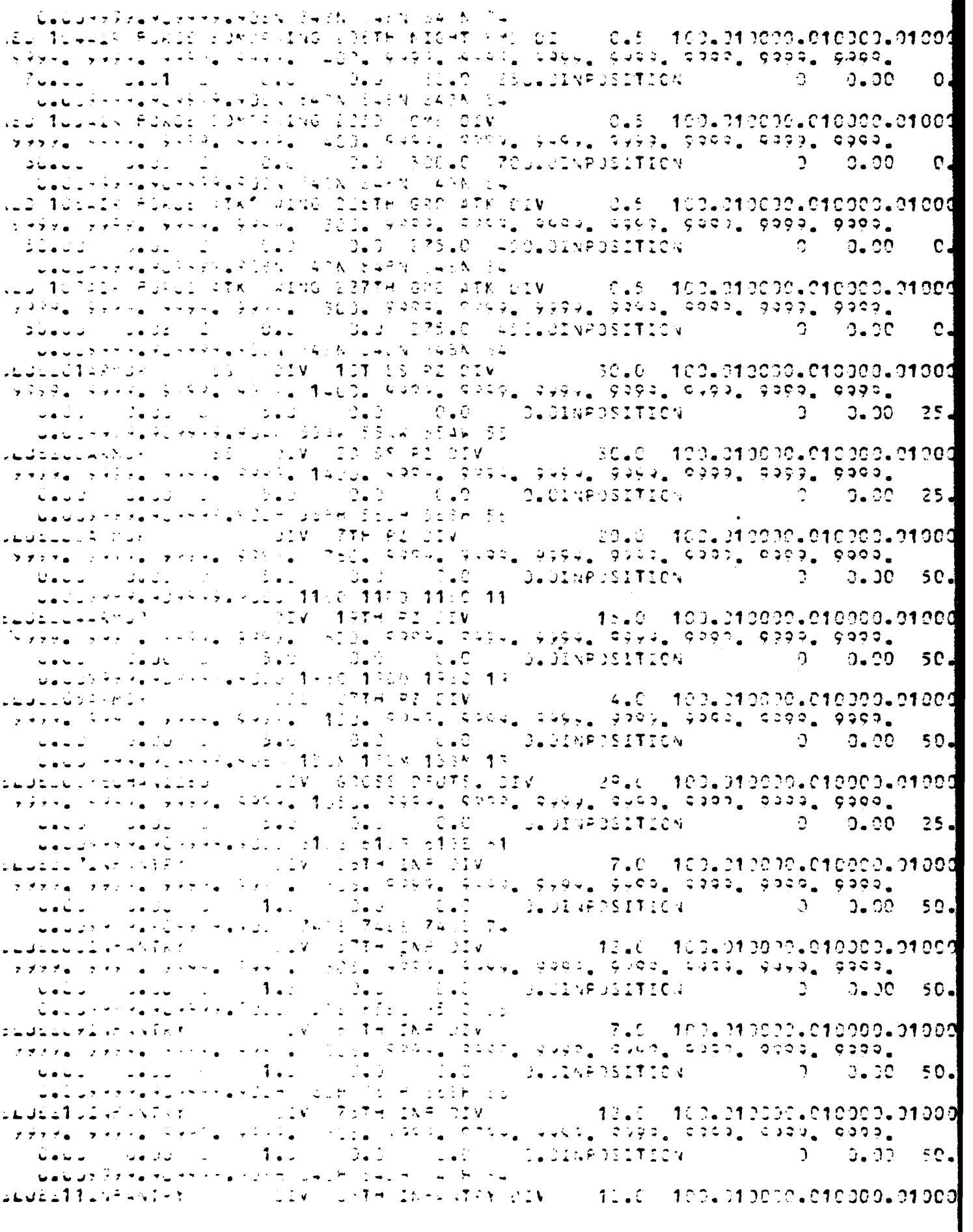


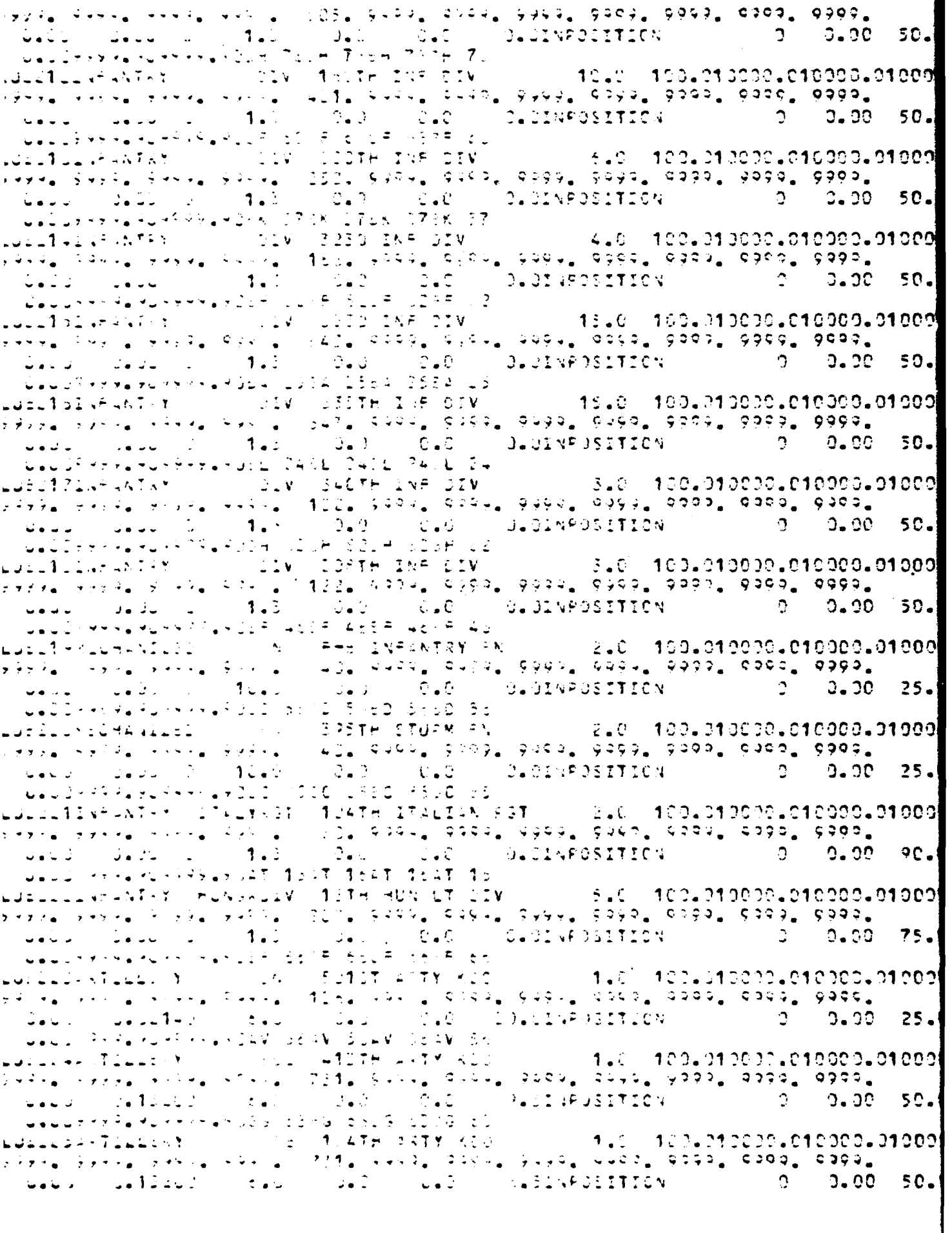


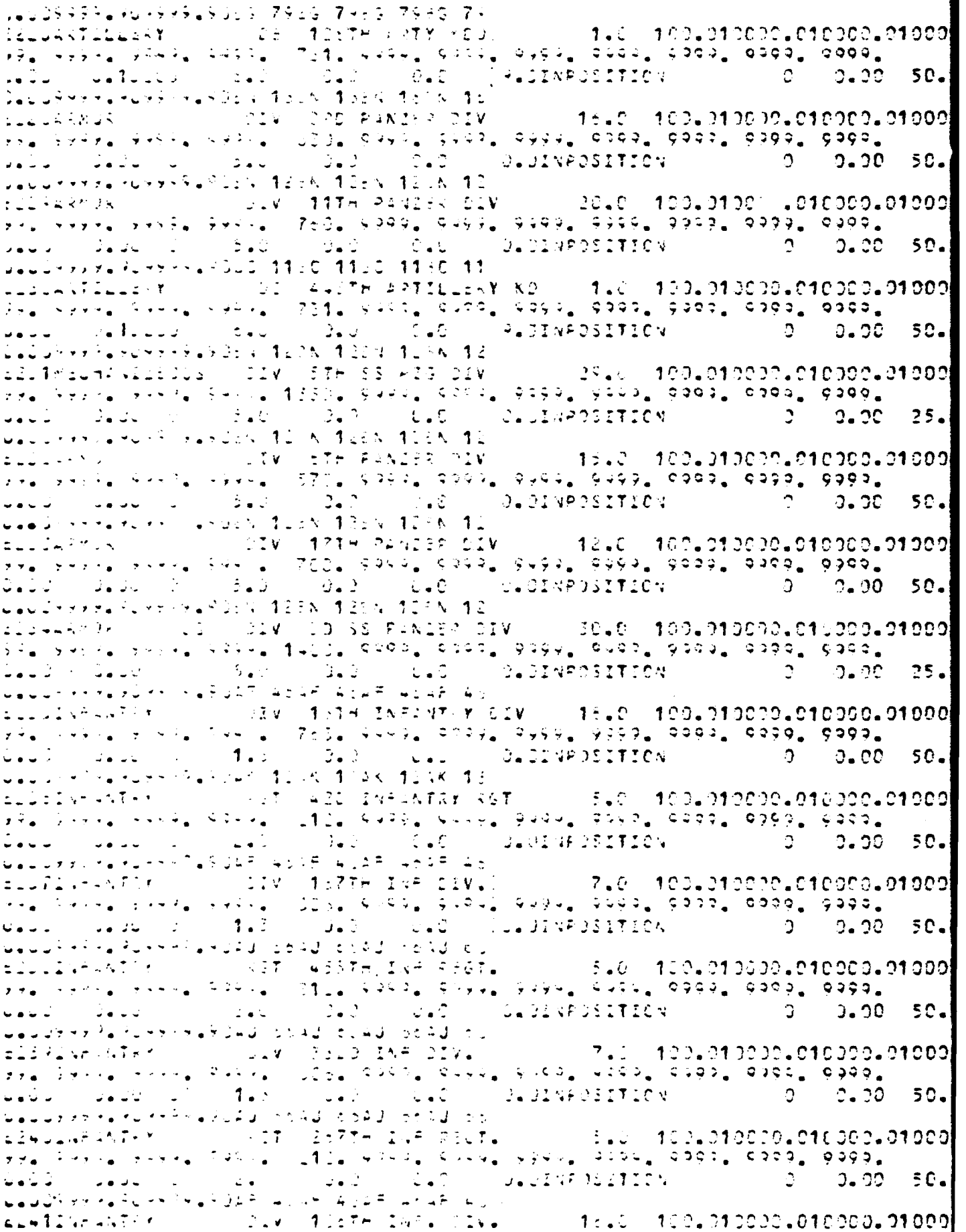


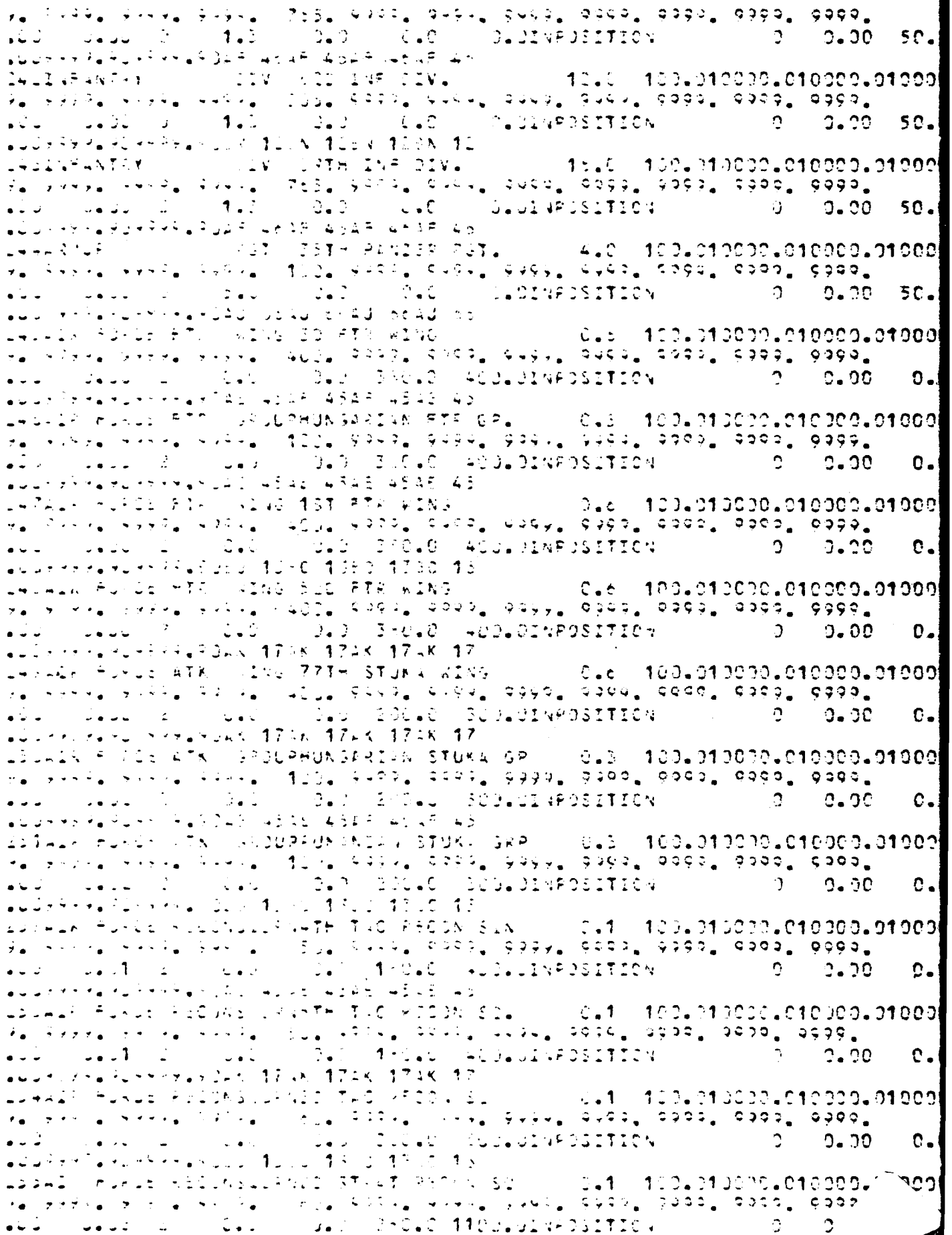


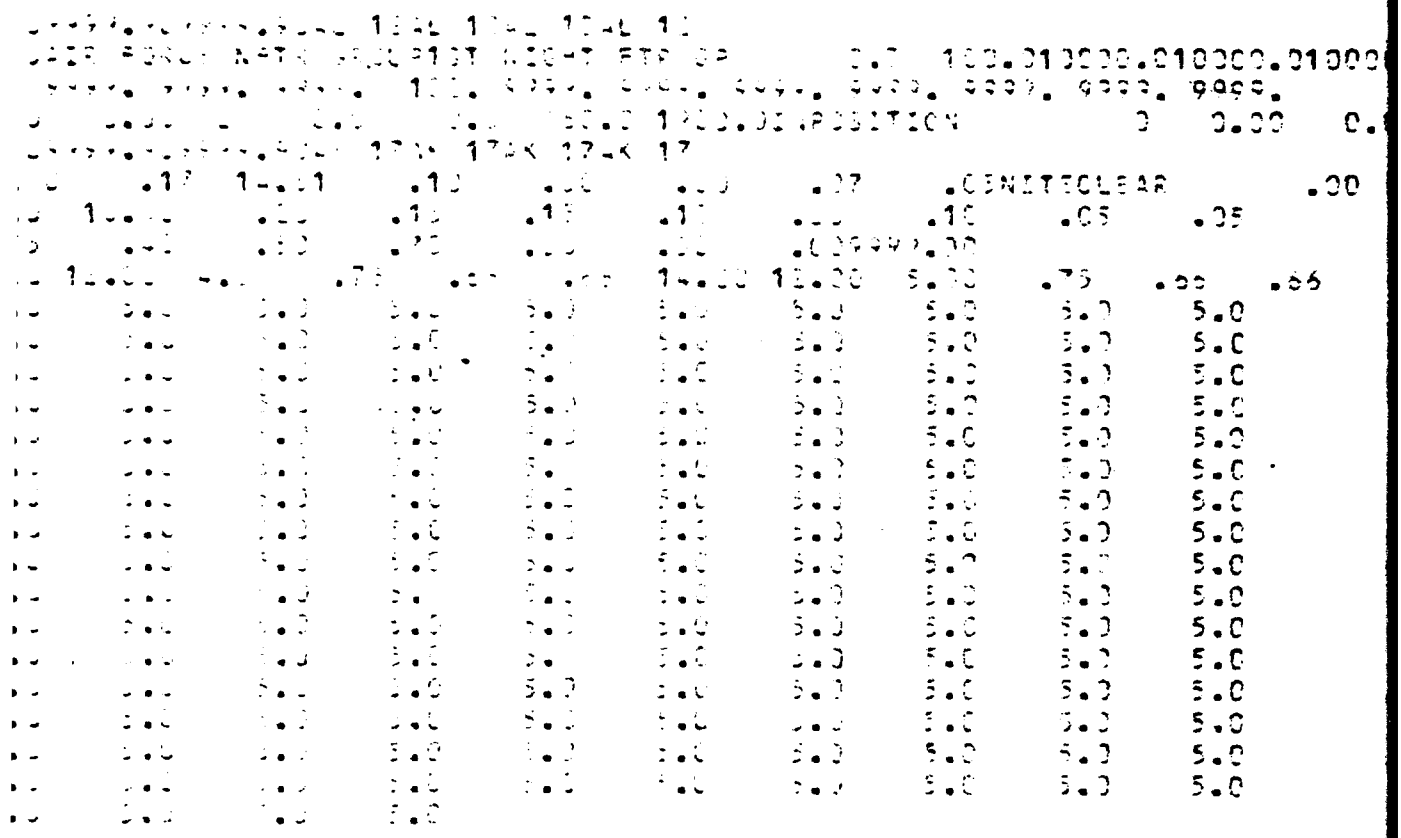












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